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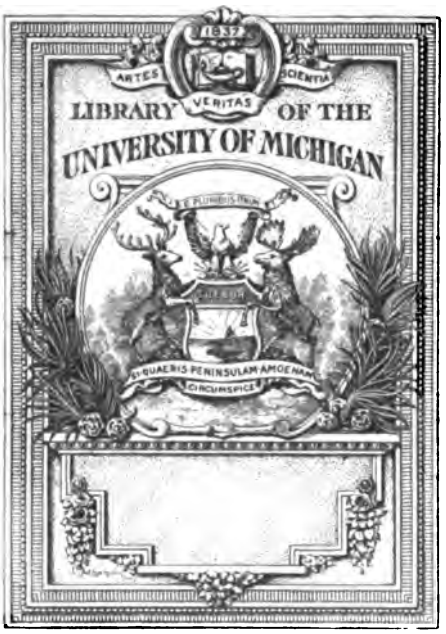

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ANDREW C. LAWSON

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UNIVERSITY OF CALIFORNIA PUBLICATIONS

BULLETIN OF THE DEPARTMENT OF

GEOLOGY

Vol. 5, No. 1, pp. 1-64, Pls. 1-6 ANDREW C. LAWSON, Editor

CARNIVORA

FROM THE

TERTIARY FORMATIONS

OF THE

JOHN DAY REGION.

BY

JOHN C. MERRIAM.

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INTRODUCTION.

In 1899 and 1900 field parties from the University of California, working under the direction of the writer, collected over the greater part of the exposed area of the Tertiary formations in the John Day Valley of Eastern Oregon. In the fall of 1900 L. S. Davis and V. C. Osmont continued in the field after the University party had returned, and made additional collections, particularly in the region of the Crooked River and Logan Butte, south of the John Day Basin. The collections of Osmont and Davis were purchased for the University, and the material now available may be considered representative of all the phases of the faunas of the John Day region. The new rodent and ungulate material from these collections has already been discussed by Dr. Sinclair.[1] In the following paper there are presented such additions to our knowledge of this fauna as have been obtained from a study of the carnivore material.

In the preparation of this report the writer has been especially indebted to Professor H. F. Osborn and Dr. W. D. Matthew of the American Museum for courtesies extended during the examination of the Cope collection of John Day types. Dr. Matthew has also very kindly made numerous examinations of types for me while the material was in the process of description. Professor W. B. Scott and Dr. Marcus Farr have shown me the types of John Day Carnivora at Princeton University, and Dr. Sinclair has recently reëxamined several types at my request.

In working over the subject of variation in the dentition and skull characters of the recent Canidae, Dr. C. Hart Merriam and Mr. Vernon Bailey have furnished most valuable data. In the examination of the Canidae, Mr. Bailey has worked over a very large series of skulls and has reported on over fifteen hundred examinations.

In justice to the artist and engraver, it should be stated that the illustrations accompanying this paper were reproduced from the first rough proofs, the original plates and drawings having been destroyed in the San Francisco fire of April eighteenth.

[1] W. J. Sinclair. Bull. Dept. Geol., Univ. Cal., Vol. 4, No. 6.

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OCCURRENCE.

The general stratigraphic succession of the Tertiary formations of the John Day region has been discussed by the writer in a previous paper.[2] The sequence of formations recognized is as follows:—

John Day River terraces	Quaternary
Rattlesnake formation	Pliocene
Mascall formation	Miocene
Columbia Lava formation	Miocene
John Day series	Miocene to Oligocene
Upper John Day	
Middle John Day	
Lower John Day	
Clarno formation	Eocene
Upper Clarno	
Lower Clarno	

Of these formations, those included in the beds below the Pliocene are made up mainly of igneous materials. The John Day and Mascall beds are almost entirely composed of volcanic ash and tuff in various forms. Mammal remains are known from the John Day, Mascall, Rattlesnake, and Terrace deposits.

Excepting the uppermost portion of the series, the John Day beds show a remarkable evenness in their stratification, and contain a fauna which is characteristic of dry land. In the higher strata, cross-bedding appears, with more or less interstratified gravel, and a number of fresh-water types are seen in the fauna. The greater portion of the series is presumably made up of slow accumulations of ash, which fell mainly on open plains, upon which shifting shallow lakes may have existed from time to time. In the latter portion of this period the topography appears to have been more diversified and the action of streams to have become more pronounced.

The greater portion of the total thickness of the Mascall is, like the John Day, made up of evenly stratified ash beds. In the lower portion of the formation there is, however, evidence of accumulation of a considerable thickness of fine sediment in a body of fresh water. In this there are numerous remains of fresh-water fishes and mollusks, and large quantities of fossil plants.

The Rattlesnake beds consist mainly of heavy gravels. Asso-

[2] Bull. Dept. Geol., Univ. Cal., Vol. 2, No. 9.

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ciated with these, as a very prominent and persistent feature, is a heavy rhyolite flow. Some of the beds beneath the rhyolite evidently represent old alluvial floors which have been built up largely by dust accumulations.

Although the Carnivora of the Tertiary faunas of the John Day region have been known through numerous types, the actual number of specimens is not large, and they may be counted as among the rarities. It is interesting to note that in the collections obtained by the University of California, there is a considerable percentage of new forms, although the number of specimens is relatively small. This indicates that the fauna is still only imperfectly represented in the collections. As yet, carnivore remains are certainly known only from the John Day and Mascall.

As far as possible in our field work, the effort has been made to determine the stratigraphic horizons in which specimens have been found. While the results of this discrimination have been most apparent in the study of the Ungulata, some light has also been thrown on the history of the Carnivora. Of the known carnivore species from this region there are still a considerable number of which the geological range or occurrence is unknown. As far as has been determined, the following are the time relations of the species. The number of specimens known to occur at each horizon is indicated by the figures in the table.

	Middle John Day	Upper John Day	Mascall
Canis (?) sp.	....	....	1(?)
Tephrocyon rurestris	....	..	1
Cynodictis (?) *oregonensis*	2	....	....
Nothocyon geismarianus mollis	1	....	....
Nothocyon lemur	3	3(?)	....
Nothocyon latidens (?)	2	....	....
Mesocyon coryphaeus	2	5	....
Mesocyon brachyops	....	1(?)	....
Mesocyon josephi (?)	1	....	....
Temnocyon altigenis	2	1(?)	....
Temnocyon ferox	....	1	....
Philotrox condoni	1	....	....
Archaelurus debilis major	7	....	....
Nimravus gomphodus	1	....	....
Pogonodon davisi	....	1	....
Pogonodon platycopis	1	....	....

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CANIDAE.

The Tertiary beds of eastern Oregon have furnished a remarkable variety of canid types compared with other formations in America. Nearly all of these are known from the John Day beds, only two of the eighteen species occurring in the Mascall. Although most of the types represented exhibit some primitive characters, much variation in structure is shown. In some cases the differentiation has led to development of considerably specialized forms. In the following discussion only those species have been touched upon, concerning which additional evidence has been obtained.

The following are the recognized species occurring in the John Day and Mascall:—

MASCALL.
- *Canis* (?) sp.
- *Tephrocyon rurestris* Condon.

JOHN DAY.
- *Paradaphaenus cuspigerus* Cope.
- *Cynodictis* (?) *oregonensis*, n. sp.
- *Nothocyon geismarianus* Cope.
- *Nothocyon lemur* Cope.
- *Nothocyon latidens* Cope.
- *Mesocyon coryphaeus* Cope.
- *Mesocyon brachyops*, n. sp.
- *Mesocyon josephi* Cope.
- *Temnocyon altigenis* Cope.
- *Temnocyon wallovianus* Cope.
- *Temnocyon ferox* Eyerman.
- *Philotrox condoni*, n. gen. and sp.
- *Oligobunis crassivultus* Cope.
- *Enhydrocyon stenocephalus* Cope.
- *Hyaenocyon basilatus* Cope.
- *Hyaenocyon sectorius* Cope.

CANIS (?) sp.

Text-figure 1.

The known material representing this species consists of two well-preserved upper molars in a fragment of a jaw. The teeth resemble those of the coyotes in general form, and are tentatively referred to the genus *Canis*. They are a little smaller than the

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molars of the living coyotes of this region, and M^2 is relatively a little larger.

Fig. 1. *Canis* sp. No. 545. Mascall beds (?), Rattlesnake Creek, near Cottonwood, Wheeler County, Oregon. × 1.

The outer cusps of M^1 are laterally compressed and rather sharp. The protocone is well developed, but the inner cusp of the cingulum is relatively small. The intermediate tubercles are both present. The outer ridge of the cingulum is well defined, but is narrow.

On M^2 the metacone is about as large as the paracone. The V-shaped protocone is distinct and the inner cusp or hypocone is well developed.

MEASUREMENTS.

	mm.
M^1, greatest antero-posterior diameter	9.7
M^1, greatest transverse diameter	13.3
M^2, greatest antero-posterior diameter	6.6
M^2, greatest transverse diameter	9.8

The only known specimen, No. 545, was obtained between Cottonwood Creek and Birch Creek, in the southeast corner of Wheeler County, Oregon. (Locality No. 887, Univ. Calif. Coll. Vert. Palae.) At this locality the Mascall formation is capped by the Rattlesnake beds. This specimen was obtained on an exposure of Mascall beds immediately below a Rattlesnake outcrop. It was not in the matrix, and we cannot be absolutely certain that it had not originally come from the Rattlesnake beds above.

TEPHROCYON, New Genus.

TEPHROCYON RURESTRIS Condon.

Pl. 1, Figs. 1, 2, and 3.

Canis rurestris Condon, The Two Islands, 1902, p. 139, Pl. 18. Type specimen No. 382, private collection of Professor Thomas Condon.

This species is represented by a very fine skull obtained by Professor Thomas Condon many years ago in the Mascall formation near Cottonwood, Grant County, Oregon. It was figured by

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Professor Condon in his work on the Two Islands and was afterward kindly loaned to the author by him for comparison and study. The skull lacks only the portion anterior to the canines. The parts present are well preserved and in good condition for study.

Distinctive Characters.—Muzzle short, posterior ends of premaxillaries extending behind the anterior ends of the frontals, sagittal crest high, inion prominent, auditory bullae very large, inferior margin of the mandible strongly convex below the anterior side of the coronoid process. Dentition $\frac{3}{3}$, $\frac{1}{1}$, $\frac{4}{4}$, $\frac{2}{3}$. P^4 with incipient protostyle, deuterocone weak. M^1 with broad internal lobe, apparently without protoconule. P_2, P_3, and P_4 with posterior basal tubercles and without anterior cusps. M_1 with well-developed metaconid, heel with low entoconid and hypoconid. Trigonid of M_2 with distinct paraconid. M_3 with three or four low tubercles or ridges.

Skull.—The type of skull shown in this species is that of a short-muzzled form with greatly developed temporal muscles. The shortening of the facial region is accompanied by relatively great backward extension of the premaxillaries, which pass the anterior ends of the frontals, and almost reach a line connecting the anterior borders of the orbits.

The sagittal crest is high and sharp. The inion projects rather more than is typical of *Canis*. The occipital region shows strong buttresses running out on either side to the lambdoidal crest. The auditory bullae are very large, and the paraoccipital processes prominent.

On the mandible, the massteric fossa is deep. The inferior margin of the jaw shows a somwhat greater degree of convexity below the anterior end of the massateric fossa than is common in the typical canids.

Dentition.—The dentition is in general much like that of *Canis,* but differs in the presence of a notch on the anterior side of P^4, which separates an incipient protostyle from the protocone; in the presence of a minute paraconid on M_2, and of several tubercles on M_3; and in the greater width of the lingual side of M^1.

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All the premolars excepting the first are represented in both jaws. The presence of the anterior one is indicated in both cases by a large alveolus. P_2, P_3, and P_4 have no anterior cusps or tubercles, but all exhibit both a posterior cusp and posterior basal tubercle. P^2 differs from all of the other premolars, excepting the carnassial, in possessing a minute anterior cusp. P^3 shows both a posterior cusp and a posterior basal tubercle. On the upper carnassial, a distinct notch on the anterior side of the protocone separates a small cusp corresponding to the protostyle. The deuterocone is small.

The first upper molar is unusually broad on the lingual side, though the posterior inner cusp or hypocone is not relatively large. A well-developed metaconule is present, but there is apparently no protoconule. The external cingulum is distinctly marked. On M^2 the protocone is large and the metacone somewhat reduced.

M_1 is not far from the stage of evolution seen in *Canis*, though the metaconid is perhaps a little larger in *Tephrocyon*. On the heel the low hypoconid and entoconid are distinctly separated. The trigonid of M_2 is less reduced than in *Canis*, and possesses a small paraconid. The heel of this tooth is not markedly different from that of *Canis*. The hypoconid is a distinct but low tubercle.

On M_3 there is a faint external ridge with three smaller ridges running toward the inner margin. These elevations seem to represent the hypoconid and the three elements of the trigonid.

Affinities.—This form seems to be generically separable from the canids thus far described from the Miocene of America, but it shows affinities with *Canis*, and to a certain extent with *Aelurodon*.

In the Canidae, the development of a protostyle on P^4 is a characteristic of the Aelurodons and *Simocyon*, though occurring occasionally in other forms. In its incipient form it is present rarely in modern species of *Canis*, particularly in the milk carnassial. In order to determine the degree of variability existing in wild canid species, Dr. C. Hart Merriam and Mr. Vernon Bailey have recently examined a large series of skulls in the collections of the Biological Survey. The following results I quote from a statement by Dr. Merriam.

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"In the big Wolf, out of 107 skulls, a faint trace of a cusp may be seen in 1 adult.

"In Coyotes, out of 450 skulls, a faint trace exists in 3 adults, and a distinct cusp is present in the milk tooth of 15 young.

"In *Canis* (or *Cerdocyon*) *magellanicus,* out of 22 skulls, no trace of a cusp in the adult; a faint cusp is present in the milk tooth of 2 out of 6 young.

"In Red Foxes, out of 244 skulls, no trace in adult; slight trace in milk tooth of 5 out of 10 young.

"In Kit and Desert Foxes, out of 70 skulls, 2 adults show trace of a cusp; 9 young have a small cusp on the milk tooth in each case.

"In the Arctic Fox, out of 24 skulls, 1 adult shows a faint trace, and 5 young in milk teeth show a faint trace.

"In *Urocyon,* out of 241 skulls, 2 adults and 3 young in milk teeth show trace of a cusp; other young show no trace.

"It is probably an exaggeration to state that any of the adults show a trace of the real protostyle."

The cusp as it appears in *T. rurestris* is stronger than in any variation of the recent *Canis* which I have seen, but it is much weaker than in *Aelurodon,* and should hardly be termed a true protostyle. This species also shows some resemblance to the Aelurodons in M^1 and M_2. It is distinguished from *Aelurodon,* among other characters, by the very imperfect development of the protostyle of P^4, the less reduced metaconid of M_1, the larger M^2, and the large inner lobe of M^1. In most of the characters in which it differs from *Aelurodon,* it approaches *Canis.*

Tephrocyon differs from *Canis* in the structure of P^4, M_2, and M_3, as indicated in the discussion of the dentition above. There are also differences in the skull. The premaxillaries pass the anterior ends of the frontals, the sagittal crest is very prominent, the otic bullae are extraordinarily large, and the mandible is strongly convex below the posterior molars.

The genus is more primitive than the typical *Aelurodons* in the imperfect development of the protostyle of P^4, and in the larger metaconid of M_1. It is more primitive than *Canis* in the characters of M_2 and M_3. The anterior molars in both jaws are near the stage of evolution seen in *Canis.* As the animal was a

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rather large form with short facial region and heavy-bladed carnassials, it was probably a rapidly specializing form. The trend of its specialization seems to have been toward the *Aelurodon* type.

Aelurodon was represented by several species in the Loup Fork epoch, but I am not aware of the existence of any remains from older beds. The Mascall beds have been thought to represent a somewhat earlier epoch than the typical Loup Fork, and it is at precisely this horizon that we would search for the ancestral type of the *Aelurodon* group. While it is not necessarily true that *Teprhocyon rurestris* is directly ancestral to *Aelurodon*, it seems to represent a tendency toward specialization in that direction in the Canidae, at the time when the genus *Aelurodon* probably had its origin, and it is evidently not far removed from this line of descent.

MEASUREMENTS.

	mm.
Length, anterior end of orbit to inion	124
Length, postorbital process to inion	97
Width between orbits	38
Width across snout above middle of superior canine	38
Length of mandible from anterior side of P_1 to posterior side of condyle	108
Height of mandible below protocone of M_1	20
Length, anterior side of P^1 to posterior side of M^2	60
Length, anterior side of P_1 to posterior side of M_3	66
Antero-posterior diameter of superior canine at base	10
P^2, antero-posterior diameter	8.5
P^3, antero-posterior diameter	10
P^4, antero-posterior diameter	17
P^4, greatest transverse diameter	9.5
M^1, antero-posterior diameter	13
M^1, greatest transverse diameter	16
M^1, antero-posterior diameter across protocone	10
M^2, antero-posterior diameter	7.7
M^2, greatest transverse diameter	12
P_2, antero-posterior diameter	7.5
P_3, antero-posterior diameter	9
P_4, antero-posterior diameter	11.5
M_1, antero-posterior diameter	20
M_1, antero-posterior diameter of heel	6
M_2, antero-posterior diameter	11.5
M_2, antero-posterior diameter of heel	4
M_3, antero-posterior diameter	5

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CYNODICTIS (?) OREGONENSIS, n. sp.

Pl. 2, Figs. 4 and 5.

Canis gregarius Cope, Bull. U. S. Geol. Surv. Terrs., 1879, p. 58.

Galecynus gregarius Cope, Tertiary Vertebrata, p. 917, Pl. 68, Figs. 5 to 8.

The specific name *oregonensis* is here applied to the John Day representatives of *Cynodictis* (?) (*Galecynus*) *gregarius* Cope. The John Day form has generally passed under the same name as the species from the White River. It is to be distinguished from the latter by the constant presence of a posterior cusp in addition to the anterior and posterior basal tubercles on P_2, the larger M^2, larger brain case, less pronounced postorbital constriction, and other characters.[3]. Scott[4] has already pointed out that "the John Day specimens, which Cope has referred to *Cynodictis gregarius,* have an even fuller cranium and shallower postorbital constriction, which should, perhaps, be reason for separating these animals specifically from the White River forms."

This species is represented in our collections by several specimens. The most important of these is a mandible (No. 316, pl. 2, fig. 4) showing the dentition excepting the median incisors, P_1, and M_3. In addition to this there is a jaw fragment with the unworn M_1 and P_4, and several fragmentary mandibles. A fragment of a maxillary (No. 1179) with both molars perfectly preserved may also belong here.

In the specimens which have come under my observation the characters mentioned above are constant. Compared with the other species of the John Day fauna, the lower sectorial is also diagnostic. The dimensions of the tooth are near those of specimen No. 10256, discussed below with *N. latidens.* It is distinguished from this form by the absence of the postero-external tubercle on the base of the protoconid, by the more distinctly

[3] In recent correspondence regarding comparisons of specimens at the American Museum, Dr. W. D. Matthew has added the following to the above mentioned characters, distinguishing this form from *C. gregarius:* "Skull wider; muzzle somewhat wider; interorbital width somewhat greater; premolars and carnassials slightly smaller; M^1 more quadrate internally, the hypocone crescent extending farther forward around the protocone; M_2 much larger."

[4] W. B. Scott. Canidae of the White River Oligocene, p. 368.

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basin-shaped talon, and by the absence or weak development of the external cingulum, excepting a faint ridge below the paraconid. The hypoconid and entoconid are sharply compressed ridges connected posteriorly, while in the form represented by No. 10256 the entoconid is smaller, is nearly conical and is not so closely connected with the hypoconid. On M_2 there is a small but acute paraconid. Although smaller than the other tubercles of the trigonid, it is nevertheless distinctly developed. The enamel of most of the premolars and molars is strongly wrinkled.

It seems not improbable that the lower jaws referred to *Galecynus lemur* by Cope really belonged in *C.* (*?*) *oregonensis*. None of the specimens described by him were in association with crania. The dimensions of his specimens are almost identical with those of *oregonensis*. As indicated elsewhere,[5] there is some reason to believe that a number of the very small inferior sectorials showing the peculiar characters of *latidens* really represent *lemur*.

MEASUREMENTS.

	No. 816	No. 865	No. 584
Length of mandible, anterior side canine to posterior side P_4	23.8 mm.		
Height of mandible below protoconid of M_1	8		
P_2, antero-posterior diameter	4.5		
P_4, antero-posterior diameter	6.2	5.9	7
M_1, antero-posterior diameter	8.2	7.9	10.5
M_1, antero-posterior diameter of heel	2.7	2.7	3.6

A skull fragment (No. 584, see measurements above) showing a perfect inferior sectorial with P_3, P_4, the trigonid of M_1, and a part of the first upper molar represents an animal considerably larger than the typical *C.* (*?*) *oregonensis*. The form of the teeth is much the same as in *oregonensis* and is quite different from that in *latidens* and *geismarianus*. I think it is very doubtful whether this form belongs in *oregonensis*, but the amount of variation shown in all the groups of John Day dogs is so great that I hesitate to separate it until more is known concerning it.

[5] See p. 16, this paper.

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NOTHOCYON GEISMARIANUS Cope, n. var. MOLLIS.

Pl. 2, Fig. 1, and Pl. 3, Fig. 1.

Type specimen No. 90, Univ. Calif. Col. Vert. Palae. From the Middle John Day Beds at Turtle Cove, John Day River, Oregon.

A perfectly preserved cranium with dentition represents a type differing somewhat from the other small canids of the John Day. The skull is that of an adult animal with somewhat worn teeth. It is much larger than the skull of *lemur* and considerably smaller than the typical *geismarianus*. The brain case is large and the facial region short. The orbits are smaller than in *lemur*, while the auditory bullae are relatively as large as in that species. The cranium is rather sharply constricted behind the acute postorbital processes. The temporal ridges show a lyrate arrangement, though it is not so strongly marked as in *lemur*. The ridges are separated by a space from 9 to 12 mm. wide, excepting over the posterior portion of the brain case, where they unite to form a low crest about 15 mm. in front of the inion. The dentition represents a stage between that of *Cynodictis(?) oregonensis* and *N. latidens*. P^3 seems to have had a posterior cusp, though the posterior margin is worn and only a trace of the cusp is preserved. The superior carnassial and the molars are of the broad type, but are narrower than in *latidens*. Except for the somewhat smaller size, lyrate arrangement of the temporal ridges and somewhat narrower molars, this form is close to *N. geismarianus*. It differs from *C. (?) oregonensis* in its larger size, larger brain case, much larger otic bullae, longer lyrate temporal area, and broader teeth.

This specimen represents a variation of the *Nothocyon* type which cannot be placed in any of the described species without apparently extending the limits of the group so far as to overlap some other species. The uniting of any of the types now known does not seem advisable until more is known of intermediate stages. Neither does it seem desirable to increase the number of species where considerable variation is suggested. I have therefore referred to this form as a variant of the *geismarianus* type. Later investigations may show that it should be raised to specific rank.

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Approaching *Cynodictis* (?) *oregonensis* rather closely, as it does, this form makes a separation of the John Day *Cynodictis* type from the more specialized *Nothocyon* very difficult, if it is really possible.

MEASUREMENTS.

	mm.
Length, premaxillary to inion	104
Length, postorbital process of frontal to inion	54
Length of superior dental series	50
P^3, antero-posterior diameter	6.2
P^4, antero-posterior diameter	9
P^4, transverse diameter across deuterocone	5.2
M^1, antero-posterior diameter	7.4
M^1, transverse diameter	9.2
M^2, antero-posterior diameter	4.6
M^2, transverse diameter	7.2
Long diameter of otic bulla	19
Width between otic bullae	7
Elevation of inion above foramen magnum	16
Width between canines	12.5
Length of superior dental series including canine	44

NOTHOCYON LEMUR Cope.

Pl. 2, Figs. 2, 3, 6, 7, and 8.

Galecynus lemur Cope, Bull. U. S. Geol. Surv., v. 6, p. 181, and Tertiary Vertebrata, p. 931.

Cynodictis lemur (Scott), Trans. Amer. Phil. Soc., 1898, p. 400.

Nothocyon lemur (Wortman and Matthew), Bull. Am. Mus. Nat. Hist., v. 12, p. 127.

This species is represented by two crania, by several upper jaws with well-preserved teeth, and by a number of loose molars. Several lower sectorials and jaws discussed under the next species possibly belong here also. Although no mandibles have as yet been found in association with crania, there seems to be some reason for believing that the inferior dentition of *lemur* is much like that of *latidens,* as is indicated in the discussion of *latidens* following.

The following measurements of upper teeth of several individuals of the *lemur* type show considerable variation, but all point toward this species rather than *latidens.*

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MEASUREMENTS.

	N. latidens Type	*N. lemur* Type[6]	*lemur* Cotype Cope[7]	No. 56	No. 15	No. 352
P^4, antero-posterior diameter	7	7	7	7.2	....	....
M^1, antero-posterior diameter	7	5	5.8	5.8	5.3	5.3
M^1, transverse diameter	8	7.8	7.8	7.4	7.4	7
M^2, antero-posterior diameter	4.5	3.8	3.5	3.6	....	....
M^2, transverse diameter	5	5.2	5	5.25	....	....

In a small cranium (pl. 2, fig. 2. No. 10208) having the general form and dimensions of *lemur,* the snout is exceedingly narrow, the temporal ridges do not unite posteriorly and the brain case is relatively very large. It appears even larger than in *lemur,* and the superior outline is strongly convex over the parietals.

Another small, narrow-nosed skull evidently belonging in *lemur* exhibits a perfectly preserved brain cast (pl. 2, fig. 3, No. 10209) illustrating the principal features of both cerebrum and cerebellum. This specimen resembles *lemur* in dimensions and general form. In most respects the brain of this species is strongly similar to that of *Cynodictis* as figured by Scott[8] for *C. gregarius* of the White River.

NOTHOCYON LATIDENS Cope.

Pl. 2, Figs. 6 and 7.

Galecynus latidens Cope, Bull. U. S. Geol. Surv., Vol. 6, p. 181, 1881.
Cynodictis latidens (Scott), Trans. Am. Phil. Soc., 1898, p. 400.
Nothocyon latidens (Wortman and Matthew), Bull. Am. Mus. Nat. Hist., Vol. 12, p. 127.

In our collection there is a perfectly preserved and unworn inferior carnassial (pl. 2, figs. 6 and 7, No. 88) exhibiting a feature which Cope considered characteristic of *latidens, viz.,* the "possession of a narrow tubercle at the external base of the principal cusp." There is also a very small tubercle anterior to the base of the entoconid. The length of this tooth is somewhat less than that of the type of *latidens,* and the heel is relatively short.

[6] No. 6888, Amer. Mus. Nat. Hist., Col. Vert. Palae.
[7] No. 6889, Amer. Mus. Nat. Hist., Col. Vert. Palae.
[8] W. B. Scott. Canidae of the White River Oligocene, 1898. Trans. Am. Phil. Soc., Vol. 19, Pl. 19, Fig. 12.

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In another specimen (No. 10256) consisting of a large portion of a lower jaw with P_4 and M_1, the external tubercle at the base of the protoconid and the smaller one anterior to the entoconid are both present. The external tubercle is, however, greatly reduced by wear without the remainder of the tooth appearing much worn. The dimensions of this jaw and of the heel of M_1 are considerably less than those of the type of *latidens,* and are nearer the dimensions required by *lemur.* These relations together with the fact that the jaws described as *lemur* agree with *Cynodictis* (?) *oregonensis* seem to indicate that the small sectorials just described possibly belong to *lemur,* and that the presence of the external tubercle on the base of the protoconid is a characteristic of *lemur* as well as of *latidens.*

MEASUREMENTS.

	No. 10256	No. 88	Type spec. *latidens*	Type spec. *lemur*
P_4, antero-posterior diameter	6	....	5.5	....
M_1, antero-posterior diameter	8.2	7.6	8	8
M_1, antero-posterior diameter of heel	2.8	2.8	3.5	*3
Depth of ramus at sectorial	8	....	10.5	8

MESOCYON CORYPHAEUS Cope.

Temnocyon coryphaeus Cope, Proc. Philad. Acad., 1879, p. 180; and Tertiary Vertebrata, p. 906.

Mesocyon coryphaeus (Scott), Princeton College Bull. 2, No. 2, p. 38, Apr., 1890.

Hypotemnodon coryphaeus (Eyerman), Am. Geol., Vol. 14, p. 321, 1894.

This species is represented in the collection by several crania and mandibles. Specimen No. 1383 shows the complete upper dentition, of which particularly the sectorial and the molars are unworn and in perfect state of preservation. In No. 1165 the upper dentition is complete excepting the incisors. Both of these specimens agree with Cope's type very closely in their measurements. Another cranium (No. 1692) representing the genus *Mesocyon* differs from both *M. coryphaeus* and *M. josephi,* and has been made the type of a new species described below.

* According to Cope's figure, Tert. Vert., Pl. 70, Fig. 7*a*.

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A well-preserved mandible (No. 1307) shows the type of dentition in *M. coryphaeus.* The sectorials are somewhat worn, so that no internal tubercle is shown. The tuberculars are very imperfectly preserved. On another specimen (No. 10366) the last two premolars, the sectorial, and the first tubercular are perfectly preserved. The measurements of these jaws, as also of several detached teeth, are considerably less than those of the type of *M. coryphaeus,* as is indicated in the measurements below. Although Cope states that the mandible described by him was associated with the smallest of the several skulls available, I find that the dentition of mandible No. 1307 in our collection fits the dentition of the skulls of *coryphaeus,* particularly that of No. 1165, very closely, and seems also to have the dimensions required for the mandible of the type cranium. The measurements available seem to indicate considerable variation in size among the forms of this group.

MEASUREMENTS.[10]

	Type	No. 1307	No. 599	No. 10366
M_1, antero-posterior diameter	18	16.5	15	14.5
M_2, antero-posterior diameter	.....	.....	....	7.3
P_4, antero-posterior diameter	11	10	....	10.5
P_3, antero-posterior diameter	.....	9.4	....	8.7
Height of jaw below protoconid of M_1	19.3	17	....	18
Height of jaw below protoconid of P_3	.....	15	....	.....

MESOCYON BRACHYOPS, n. sp.

Text-figure 2.

Type specimen No. 1692, Univ. Cal. Col. Vert. Pal. From the upper portion of the John Day series at Logan Butte, Crook County, Oregon.

Facial region and palate relatively shorter than in either *M. coryphaeus* or *M. josephi.* Superior dental series somewhat crowded anteriorly, so that P^1 is very close to the canine. Superior sectorial and first tubercular with dimensions near those of *coryphaeus,* and absolutely larger than in *josephi.* The brain case is relatively larger than in *coryphaeus.*

[10] See also measurements of superior dental series of *coryphaeus* below, p. 19.

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Fig. 2. *Mesocyon brachyops,* n. sp. No. 1692. John Day beds, Logan Butte, Crook County, Oregon. × ½.

This is evidently a true *Mesocyon* near the *coryphaeus* type, possessing like that form both posterior cusp and basal tubercle on P^3. The sectorial is nearly as large as in *coryphaeus.* P^3 and P^2 are relatively smaller. The palate is as wide posteriorly as in *coryphaeus,* and the width between the canines is also as great, but the palate of the typical *coryphaeus* is 15 to 20 per cent. longer. There is a moderate degree of crowding of the premolars anteriorly, in contrast to the open arrangement in *coryphaeus* and *josephi.* The size of the brain case is relatively considerably greater than in the type of *coryphaeus* or in a specimen of the same general dimensions in our collection. *M. josephi* differs from this form in having a longer palate, a smaller superior sectorial and first molar, and in lacking a posterior cusp on P^3.

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The presence of this short-faced variety in close association with long-faced forms of the same group is another illustration of the interesting tendency toward the evolution of short-faced forms in the John Day.

MEASUREMENTS.

	M. josephi Type	*M. brachyops* Type, No. 1697	*M. coryphaeus* Type	*M. coryphaeus* No. 1165	*M. coryphaeus* No. 1883
Length, premaxillary to occipital condyle inclusive	.....	134	160	.....	.....
Length, posterior side of C to posterior side of M^1	47*	43.4	50*	*a*51	53
Antero-posterior diameter of canine	.....	9	11*	.....	.....
P^1, antero-posterior diameter	3.8*	4.1	4.5*	4.1	4.6
P^2, antero-posterior diameter	8.7*	7	8.5*	8.4	9.+
P^3, antero-posterior diameter	9	8.4	9.5	9.6	10.+
P^4, antero-posterior diameter	12.5	14.2	15	13.6	14.2
P^4, transverse diameter across deuterocone	7	8.3	9*	8.4	8.6
M^1, antero-posterior diameter	8	8.5	9*	9	9.8
M^1, transverse diameter	11	14.3	15*	*a*13.4	15.3
M^2, antero-posterior diameter	4		4.3*	5	5.2
M^2, transverse diameter	7.5		8*	9	9.7
Width of palate between deuterocones of sectorials		26	26.5*	.....	.....
Width between canines	.....	17	17	.....	.....
Length postorbital process to inion		74	86*	.....	.....
Greatest transverse diameter of brain case	.....	43.5	45*	.....	.....
Greatest height of brain case above meatus auditorius	.....	32	32*	.....	.....

MESOCYON JOSEPHI Cope (?).

Temnocyon josephi Cope, Bull. U. S. Geol. Surv. Terrs., Vol. 6, p. 179; and Tertiary Vertebrata, p. 912.

Hypotemnodon josephi (Wortman and Matthew), Bull. Am. Mus. Nat. Hist., Vol. 12, p. 130.

Mesocyon josephi (Hay), Bull. U. S. Geol. Survey. No. 179, p. 773.

A mandible somewhat smaller than the lower jaw of *M. coryphaeus* figured by Cope is not far from the size required for the

*[11] In the absence of other data, these measurements are taken from Cope's figures of the type (*op. cit.*, Pls. 70 and 71), and will probably be found to differ slightly from the exact measurements of the specimen.

a Approximate.

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jaw of *M. josephi,* and may represent that species. This specimen (No. 364) shows distinctly the structure of P_2, which has not been described in *Mesocyon.* This tooth has both anterior and posterior basal tubercles in addition to a well-developed posterior cusp. The heel of the sectorial, although slightly damaged, seems to differ from that of the typical *Mesocyon coryphaeus.* The hypoconid is somewhat smaller and lower, and the entoconid is relatively larger, the type of heel being as well adapted to crushing as to cutting. M_2 and M_3 are represented only by the roots and alveoli. They both appear to have been relatively large teeth, and M_3 had two roots instead of one as in *coryphaeus.* If this is *M. josephi* there may be reason to believe that this species is a characteristic form of the Middle John Day, while the larger *coryphaeus* seems to have been common in the Upper John Day, though possibly present in the middle division also.

MEASUREMENTS.	mm.
M_1, antero-posterior diameter	15.5
P_4, antero-posterior diameter	8.8
P_3, antero-posterior diameter	7
Height of jaw below protoconid of M_1	16
Height of jaw below protoconid of P_2	15

INDETERMINATE.

Text-figures 4, 5, and 6.

Several loose teeth, which have not been connected with determinable specimens, show peculiar characters of the inferior molars not recognized as yet in any of the John Day canids. In text-figure 4 there is shown the heel of a M_2 and a perfect M_3 preserved in a jaw fragment (No. 672) found at the same locality in the Middle John Day beds with specimen No. 364 tentatively referred above to *M. josephi.* In this specimen the entoconid and hypoconid of M_2 are both well developed. M_3 is a broad tooth with a large talon. The small protoconid and the metaconid are very close together, and the paraconid shelf is much reduced. The entoconid and hypoconid are larger and farther apart than the tubercles of the trigon. In *Mesocyon coryphaeus* the talon of M_2 supports a single tubercle. The second and third inferior molars of *M. josephi* are unknown, though

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one might suspect from the character of the specimen described above that they are broader than in *M. coryphaeus*. The heel of M_2 in *Philotrox condoni* is broader than in *M. coryphaeus*, but does not show a development of the entoconid and hypoconid comparable to that seen here. The form of M_2 in *Oligobunis* appears to be quite different from that in this specimen, and M_3 is absent. M_2 is said to be trenchant in *Enhydrocyon* and is unknown in *Hyaenocyon*.

3 4 5 6

Fig. 3. *Mesocyon coryphaeus* Cope. Inner side of right M_1. No. 599. Upper portion of John Day Series, Haystack Valley, John Day River, Oregon. × 1.

Fig. 4. Indeterminate. Superior aspect of left M_2 and M_3. No. 672. Middle John Day, below Clarno's Ferry, John Day River, Oregon. × 1½.

Fig. 5. Indeterminate. Superior aspect of right M_1. No. 1516. Upper John Day, Turtle Cove, John Day Valley, Oregon. × 1.

Fig. 6. Outer side of M_1 shown in fig. 5. × 1.

Another peculiar specimen (No. 1516), text-figures 5 and 6, representing a portion of an inferior sectorial with a well-preserved heel, was found in the Upper John Day beds at the lower end of Turtle Cove. It shows a hypoconid and an entoconid of almost exactly equal size. It is distinguished from the sectorial of the jaw tentatively referred to *M. josephi* by the presence of a distinctly marked basal band on the outer side of the talonid. This tooth differs from all of the John Day canids with which I am acquainted. It may represent a *Mesocyon* or possibly one of the short-jawed forms.

TEMNOCYON ALTIGENIS Cope.

Pl. 3, Fig. 2, and Text-figures 7, 8, 9, 10, and 11.

Temnocyon altigenis Cope, Palaeont. Bull. No. 30, p. 6, 1878; Rep. U. S. Geol. Surv. Terts., Vol. 3, p. 903, Pl 68, Fig. 9, 9*a*, 9*b*, Pl. 70, Fig. 11.

This species, constituting the type of the genus *Temnocyon*, has been only partially known, and was considered by Cope as

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one of the rarer John Day carnivores. It is represented in the University collections by two specimens, No. 9999, a young adult with unworn teeth, and 1549, an old individual with teeth considerably worn. No. 9999 shows the entire skull with the complete upper and lower dentition, and the greater part of the skeleton excepting the manus and the distal half of the pes. The other specimen is a nearly complete cranium with all the elements of the upper dentition. The dentition of the mandible in the first specimen corresponds very closely to that of Cope's type. The upper dentition is nearer in form to that of Cope's type of *altigenis* as figured than to any other species, with the exception of the deuterocone of the carnassial. In this tooth our specimens exhibit the heavy form of deuterocone seen in the type of *T. ferox.* In Cope's specimen showing the upper jaw, the deuterocone of P^4, though prominent, is represented as small, low, narrow, and not very sharply separated from the protocone. Although this cranium was not associated with the type, the molars show so close a resemblance to those of specimen No. 9999 that there seemed to be good reason for believing that the deuterocone of P^4 had not been correctly drawn. Dr. W. D. Matthew has very kindly examined Cope's type of the cranium for me recently to ascertain the true character of this tooth, and finds that "the upper fourth premolar has a large, well separated deuterocene." The molars of this specimen were found by Dr. Matthew to be correctly represented. With this correction of the original description of *Temnocyon altigenis,* specimens No. 1549 and No. 9999 approach this species very closely. The principal difference being found in minor variations of the measurements as seen in the table of measurements on page 29. Both of the specimens used as types by Cope are slightly larger than the specimens in our collection.

The differences separating this species from the other members of the genus *Temnocyon* may be expressed as follows:—

T. ferox Eyerman. Largest known species. Length of skull in type specimen 266 mm. Sagittal crest high. Deuterocone of P^4 large and heavy, sharply separated from protocone, with an incipient tubercle on the anterior side. P^3 with posterior basal tubercle. M^1 with V-shaped protocone. M^2 with greatly reduced metacone. P_4 practically equaling M_1 in length, with a distinct

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posterior basal tubercle in addition to the prominent cusp arising from the posterior side of the protoconid.

T. altigenis Cope. Species of medium size. Length of skull 178 mm. in No. 9999, somewhat greater in No. 1549. P^4 heavy and wide anteriorly; deuterocone very large and heavy, separated from protocone by deep valley, without anterior conule. P^3 without posterior basal tubercle. Protocone of M^1 nearly conical, regularly rounded posteriorly but with a short antero-external ridge. M^2 with metacone smaller than paracone, but considerably larger than in the other species. P_4 considerably shorter antero-posteriorly than M_1, with prominent cusp on posterior side of protoconid and with incipient posterior basal tubercle.

T. wallovianus Cope. Species of medium size. Deuterocone of P^4 apparently not greatly enlarged. P^3 without posterior basal tubercle. M^2 small, with reduced metacone. This species should possibly be included in *T. altigenis*.

The principal features of the skeleton of *T. altigenis* as shown in specimens 9999 and 1549 mainly confirm the generic characters represented in the specimen of *T. ferox* described by Eyerman. In some cases, however, the specific differences are great enough to modify slightly our estimate of the generic characters based on the description of *ferox*.

Skull.—The skull of *T. altigenis* differs considerably from that of *ferox* in general outlines. As represented by Eyerman,[12] the cranium of *ferox* is relatively high and narrow compared with the undistorted specimen of *altigenis* seen in No. 1549. A part of this difference may be due to lateral crushing in the *ferox* specimen, which would produce the deviation in height and width at the same time. The palate of *altigenis* is decidedly narrow, but that of *ferox* is extreme in this respect. In *ferox* the sagittal crest is high and narrow over the greater part of the brain case; in specimens 1549 and 9999 the sagittal ridge is very low excepting over the most posterior portion of the brain case, where it attains a considerable height. In specimen 9999 the ridge is divided almost to the posterior third of its length by a sharp but very narrow groove. The lambdoidal crest is strong and high.

The broad frontal region is slightly concave in front of the

[12] J. Eyerman. Amer. Geol., Vol. 17, p. 267.

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postorbital processes, but is convex immediately behind these points in specimen 1549. The postorbital processes are very short and blunt. The nasal region is characterized by the shortness of the nasal bones, which do not reach back to a line drawn between the anterior borders of the orbits. They are considerably shorter than in *Daphaenus* or in *Mesocyon*.

The zyogamatic arch is not especially robust. The postglenoid process is long and acute. The paroccipital process is shorter and less acute than in *ferox*, and is not directed downward as much as in that species.

The anterior and posterior palatine foramina are small. The anterior border of the posterior nares is situated considerably behind the last molars. The nasal chamber is narrow and the inferior borders of the lateral walls are arched inward, giving it a more nearly tubular form than is seen in *Canis*. The lachrymal and optic foramina, and the sphenoidal fissure have much the same relations as in *Canis*. The optic foramen, the sphenoidal fissure, and the foramen rotundum are in a distinct groove separated from the region above by a sharp ridge. The foramen rotundum is very close to the sphenoidal fissure in the recessed posterior end of this depression. The posterior opening of the alisphenoid canal is almost hidden inside the foramen ovale. The postglenoid foramen is nearer the median line of the skull than is the lowest part of the postglenoid process. The relations of the condylar foramen are much as in *Canis*. The foramen lacerum posterius seems relatively small. The postparietal foramina are situated at about half the height of the brain case.

The arrangement of many of the foramina, particularly the postglenoid and the posterior opening of the alisphenoid canal, is much like that in *Daphaenus felina* as described by Hatcher.[13]

Dentition.—The generic characters of the dentition of *Temnocyon* have already been fully discussed by Cope,[14] Schlosser,[15] Scott,[16] Eyerman,[17] Wortman and Matthew.[18] The observations

[13] J. B. Hatcher. Oligocene Canidae., Mem. Carnegie Mus., Vol. 1, No. 2, p. 75.
[14] Cope, E. D. Tert. Vert., p. 902.
[15] Schlosser, M. Beitr. z. Pal. Oestr-Ung., B. 4, p. 280.
[16] Scott, W. B. Trans. Am. Phil. Soc., Vol. 17, p. 73.
[17] Eyerman, J. Amer. Nat., Vol. 17, p. 268.
[18] Wortman and Matthew. Bull. Am. Mus. Nat. Hist., Vol. 12, p. 115.

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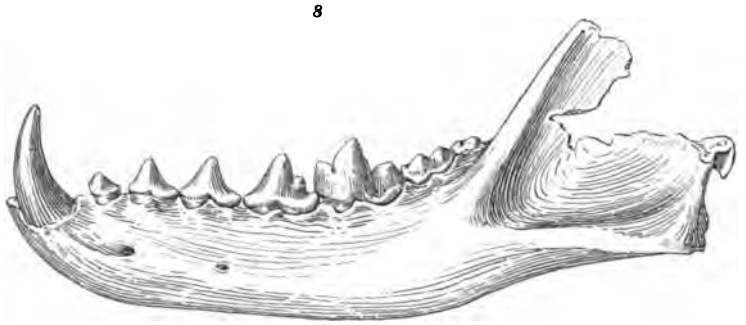
of these writers are only confirmed by the excellent material of *altigenis* now available. These specimens show that in this species the deuterocone of P^4 is extraordinarily large compared with that in most typical canids. The same feature is seen in *ferox*, and the deuterocone of P^4 in *wallovianus* is also larger than is indicated in Cope's figure of this form; so that this character may be considered diagnostic of the genus. The reduced and almost rounded form of the protocone of M^1 is evidently characteristic of *altigenis*, but is not marked in either *ferox* or *wallovianus*. M^2 is relatively larger in *altigenis* than in the other species.

7

8



9

Fig. 7. *Temnocyon altigenis* Cope. Inferior aspect of right superior dental series. No. 9999. John Day beds, Logan Butte, Crook County, Oregon. × ⅔.

Fig. 8. *Temnocyon altigenis* Cope. Superior aspect of dentition shown in fig. 9. × ⅔.

Fig. 9. *Temnocyon altigenis Cope.* Outer side of left ramus of the mandible. No. 9999. John Day beds, Logan Butte, Crook County, Oregon. × ⅔.

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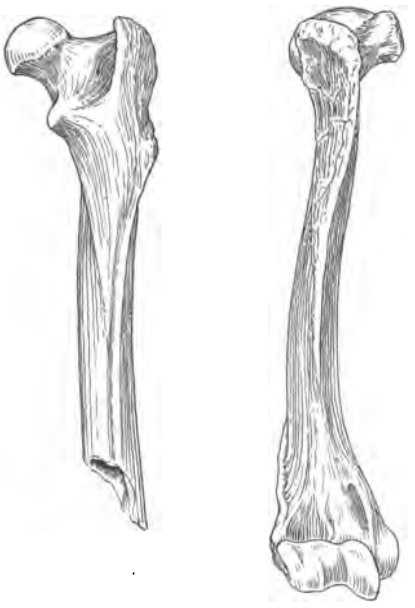
In the inferior dentition P_1, which has not been previously described, is single-rooted and simple crowned. The crown projects over the root anteriorly so that the summit is almost immediately over the anterior border of the alveolus. M_3, which has also been unknown, is a very small tooth somewhat similar in form to M_2. It has very low anterior and posterior tubercles and an antero-internal shelf without tuberculation as in M_2.



10 *11*

Fig. 10. *Temnocyon altigenis* Cope. Posterior side of right femur. No. 9999. John Day beds, Logan Butte, Crook County, Oregon. × ½.

Fig. 11. *Temnocyon altigenis* Cope. Anterior side of right humerus. No. 9999. John Day beds, Logan Butte, Crook County, Oregon. × ½.

Limbs.—Concerning the structure of the limbs, but little can be added to what Eyerman has presented in the description of *ferox*. The limb elements of *altigenis* are perhaps a little more slender than the corresponding elements of *ferox*. In the humerus the shaft is not as straight as in *ferox*. The acute deltoid ridge is extended downward for more than two-thirds the length of the bone. The supinator ridge is prominent, but not as well developed as in *Daphaenus*. The entepicondylar foramen is large.

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On the femur, the gluteal ridge and spiral line are very strongly marked. The space between them is set off as a perfectly flat, triangular area very distinctly marked off. The extension of the linea aspera below is a long, sharp ridge. The upper portion of the gluteal ridge is considerably enlarged, and is quite distinctly separated from the great trochanter. This tubercular enlargement is really comparable to a reduced third trochanter. As nearly as can be judged from comparison with the figures published by Hatcher,[19] it is similar to the development of the gluteal ridge in *Daphaenus felinus,* though Hatcher stated that a third trochanter was wanting in that form. Eyerman[20] mentions a third trochanter in *Daphaenus,* but I find no reference in his paper to the character of the femur of *Temnocyon* in this region.

The elements of the epipodial region in both anterior and posterior limbs are stated by Eyerman to be relatively short compared with the propodial segments. Unfortunately no one of these elements is perfectly preserved in specimen 9999, so that the exact measurements of length cannot be obtained. The manus is not preserved. In the pes the principal elements are present excepting the phalanges, and the structure of the foot in the main features resembles that of *ferox.*

Affinities.—In some characters this species seems to be less specialized than *T. ferox,* but in general the stage of evolution is nearly as far advanced. *T. ferox* occurs in the Upper John Day. The best known occurrence of *T. altigenis* is near the boundary between the middle and upper divisions. The relationship of *altigenis* to *wallovianus* is doubtful, though the greater reduction of M^2 in *wallovianus* may indicate that it is a more advanced form. The occurrence of *wallovianus* is unknown.

The relation of the genus *Temnocyon* to the White River *Daphaenus* has been ably discussed by Scott,[21] Eyerman,[22] Wortman and Matthew,[23] Wortman,[24] and more recently by Hatcher.[25]

[19] J. B. Hatcher. *Op. cit.,* Pl. 19, Fig. 1.
[20] J. Eyerman. *Temnocyon* and *Hypotemnodon.* Amer. Geol., Vol. 17, p. 279, 1896.
[21] W. B. Scott. Trans. Am. Phil. Soc., Vol. 17, p. 73, and Vol. 19, p. 406.
[22] J. Eyerman. *Op. cit.,* p. 283.
[23] Wortman and Matthew. *Op. cit.,* p. 118.
[24] J. L. Wortman: Am. Jour. Soc., June, 1901, Vol. 11, p. 449.
[25] J. B. Hatcher. *Op. cit.,* p. 105.

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With the support of excellent evidence, the opinion has been generally expressed that *Temnocyon* is in the line of descent from *Daphaenus*. Hatcher has described as the ancestor of *Temnocyon*, a new genus, *Protemnocyon*, based on a new species, *P. inflatus*, from the Oreodon beds. Unfortunately *Protemnocyon* was compared only with Cope's *Temnocyon coryphaeus*, which is quite distinct from the typical *Temnocyon*, and is generally recognized as a separate genus, *Mesocyon*. In some respects, *viz.*, enlarged brain case, lower sagittal crest, and reduced M^3, *Protemnocyon* represents a more advanced type than *Daphaenus*, and in the character of the molars it approaches *Mesocyon* somewhat more closely than does the true *Daphaenus*. The type ancestral to the true *Temnocyon* is approximated more nearly in *Daphaenus vetus*, as previously suggested by several writers.

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MEASUREMENTS.

	T. ferox type	*T. altigenis* type	No. 9999	No. 1545	*T. wallovianus* type
Length of skull, premaxillaries to inion	266	.....	178	.....	.....
Width of skull between upper borders of orbits	.....	.....	*a*34	39.5	.....
Width of palatine region between canines	18	.....	*a*20	*20.8	.....
Width of palatine region between deuterocones of P^4	.....	.....	*a*25.4	26.5	.....
Width of palatine region between anterior upper molars	24	.....	*a*23	25	.....
Height of inion above foramen magnum	.....	.....	32	.....	.....
Length of superior dentition, posterior side of canines to posterior side M^3	96	70	67	70	67
I^1, transverse diameter	.....	.....	2	2.4	.....
I^3, transverse diameter	.....	.....	4.4	5	.....
Superior canine, antero-posterior diameter at base of enamel	.....	.....	11	11.9	.....
P^1, antero-posterior diameter	11	.....	6.5	*a*7	.....
P^2, antero-posterior diameter	14	.....	10.4	*a*11.4	.....
P^2, greatest transverse diameter	.....	.....	4.5	.....	.....
P^3, antero-posterior diameter	17	.....	12	*a*12.8	13
P^4, antero-posterior diameter	23	19	17	18	17
P^4, transverse diameter across deuterocone	16	12.5	12	13	11
M^1, antero-posterior diameter	16.5	14	13	13.5	12
M^1, transverse diameter	25.3	20	17.75	18.5	15
M^2, antero-posterior diameter	8	7.5	7.3	8	5
M^2, transverse diameter	14	14	12	12	10
Length of mandible, anterior side of canine to condyle	204	.....	138	.....	.....
Height of mandible below P_3	31.6	24	21	.....	.....
Height of mandible below protoconid of M_1	38.3	28	22	.....	.....
P_1, antero-posterior diameter	.....	.....	6	.....	.....
P_2, antero-posterior diameter	14.8	11	10	.....	.....
P_3, antero-posterior diameter	14.2	.....	11.7	.....	.....
P_4, antero-posterior diameter	21	15	14.5	.....	.....
M_1, antero-posterior diameter	21.5	18.5	17.25	.....	.....
M_1, length of heel	7	7	5.6	.....	.....
M_2, antero-posterior diameter	13	11.5	10.25	.....	.....
M_3, antero-posterior diameter	.....	.....	5.5	.....	.....
Humerus, length	203.5	.....	155	.....	.....
Calcaneum, length	.....	.....	50	.....	.....
Metatarsal 2, length	69	.....	56.5	.....	.....

a Approximate.

[28] Measurements largely from Eyerman's figures. *Op. cit.*, Pl. 11.

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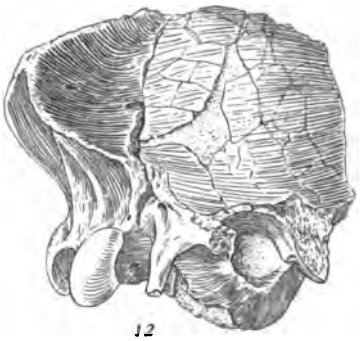
PHILOTROX, New Genus.

PHILOTROX CONDONI, new genus and species.

Text-figures 12, 13, and 14.

Type specimen No. 89, Univ. Calif. Col. Vert. Palae. From the Middle John Day, Turtle Cove, John Day Valley, Oregon.

This form is known from a single specimen found by Mr. L. H. Miller in the Middle John Day beds at locality 819, Turtle Cove, on the John Day River. There is present only the posterior part of the cranium and the left mandible, with nearly complete lower dentition. The teeth are in perfect state of preservation.



12

13

14

Fig. 12. *Philotrox condoni*, n. gen. and sp. Right side of posterior cranial region. No. 89. × ¾.

Fig. 13. *Philotrox condoni.* Superior aspect of mandibular dentition. No. 89. × ¾.

Fig. 14. *Philotrox condoni.* Outer side of mandible. No. 89. × ¾.

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Distinctive Characters.—Cranium with well-developed brain case, and large thin-walled auditory bullae. Two pair of postparietal foramina present. Mandible short, uncommonly heavy anteriorly. Dentition $\frac{3}{3}(?), \frac{1}{1}, \frac{3}{3}, \frac{3}{3}$. Premolars heavy, P_2 without basal tubercles, P_3 and P_4 with anterior and posterior basal tubercles and posterior cusp. M_1 with well-developed shear and somewhat reduced metaconid. The somewhat elevated hypoconid occupies about half of the broad heel of M_1, entoconid low. M_2 without prominent paraconid, M_3 in general like M_2.

Skull.—The fragment of the cranium shows a brain case and posterior cranial crests of moderate proportions. The crests are about as prominent as in *Mesocyon coryphaeus*. The otic bulla present is thin-walled and large. It is almost entirely separated from the postglenoid process. The paroccipital process is slender. There are two postparietal foramina, of which the larger, anterior one is situated a little more than half way up the side of the brain case and in front of the lambdoidal crest. The smaller, posterior foramen is located considerably higher up and on the base of the lambdoidal crest, much as in the postparietal foramina of *Enhydrocyon*. The postglenoid foramen is situated very close to the median border of the postglenoid process. The situation of the condylar foramen is much as in *Canis*.

The mandible is short and the posterior end of the dental series is considerably elevated. The anterior portion of the jaw is more than ordinarily heavy. The inferior border is only slightly convex. The massateric fossa reaches forward to a point below the posterior end of M_2.

Dentition.—The dentition, so far as known, is $\frac{3}{3}(?), \frac{1}{1}, \frac{3}{3}, \frac{3}{3}$. Viewed from above, the dental series is seen to curve toward the median line rather sharply in front of the last premolar as in other short-jawed forms. The enamel of all the teeth is more or less rugose.

Only one incisor, I_3 (?), is present in the jaw. It is a relatively small tooth with a small lateral cusp which is only a little lower than the principal cusp. The symphyseal region is uncommonly narrow and the space between the outer incisor and the symphysis is occupied by an antero-posteriorly elongated pit which does not include more than half of the area. A very small

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incisor evidently representing I_2 or I_1 was found loose in the matrix with the mandible. It would occupy only about half of the empty alveolus, but if the other incisor was present, one of them must have been crowded far back.

The canine is large and is somewhat heavier than in most of the associated canid forms.

Of P_1 there is no trace, though the alveolar border is perfectly preserved, and as P_2 is large and very near the canine, its absence is evidently normal. All three of the premolars are rather heavy. The first two are set somewhat obliquely in the jaw. All three are two-rooted. P_2 has no distinct anterior or posterior tubercles, though the cingulum is slightly swollen anteriorly and posteriorly. P_3 has a minute anterior basal tubercle, a posterior cusp, and an incipient posterior basal tubercle. The general structure of P_4 is similar to that of P_3, but the basal tubercles and posterior cusp are better developed.

The shear of the trigonid on M_1 is thick at the base and the blades are relatively higher than in *Canis*. The metaconid is about as large as in *Canis*. On the talonid, the base of the hypoconid does not reach inward beyond the middle of the heel. The summit of this cusp is laterally compressed, but is not as high as in *Temnocyon*. The inner half of the talonid is slightly excavated, and there are two small tubercles corresponding to the entoconid and hypoconulid on its inner and posterior borders.

M_2 shows a well-developed protoconid and metaconid, the former being somewhat the larger. On an excavated antero-internal shelf a low marginal ridge represents the paraconid. The heel is slightly hollowed and the outer border is a little higher than the inner.

The structure of the small M_3 is so far as known in general similar to that of M_2, though the paraconid shelf is smaller.

Affinities.—The type of canid described above shows considerable resemblance to the short-faced dogs which have been grouped together in the sub-family Simocyoninae. Of these there are known from the John Day three genera, *Oligobunis, Hyaenocyon*, and *Enhydrocyon*, no one of which corresponds closely to the form under discussion.

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Oligobunis differs in having four inferior premolars and two molars instead of three premolars and three molars; in the absence of an anterior basal tubercle on P_3; in the shorter heel of M_1; and in the greater width of M_2. The metaconid of M_1 in *Oligobunis* appears from Cope's figures to be considerably larger than in *Philotrox*, and the anterior portion of the lower jaw is more slender.

The imperfectly known *Hyaenocyon* has apparently the same number of inferior premolars as *Philotrox*, but in *H. basilatus* they are somewhat heavier and the anterior basal tubercles are much better developed. P_2 is markedly trilobate in this species, but is without accessory tubercles in *Philotrox*. This tooth is also relatively much smaller in *Hyaenocyon*. There is little correspondence between the inferior dentition of *Philotrox* and the dentition of *H. sectorius* in form and arrangement of the teeth. The sectorial portion of the inferior carnassial of *Philotrox* is exceedingly narrow antero-posteriorly compared with the fore and aft diameter of the upper carnassial in *H. sectorius*. The presence of the third lower molar in *Philotrox* indicates the existence of at least two molars in the upper series, while Cope confidently states that there was but a single superior molar in *H. sectorius*.

The lower jaw of *Enhydrocyon* is unfortunately even more imperfectly known than that of *Hyaenocyon*. There are probably three inferior premolars in this genus, though P_2 is unknown. The premolars are at least specifically distinguishable from those of *Philotrox*, and P_3 has no anterior basal tubercle. The heel of M_1 in *Enhydrocyon* appears to be narrower posteriorly than in *Philotrox*, and has, according to Cope,[27] "an absolutely median cutting edge." There is, however, a rudimentary entoconid at the base of this cusp. The first tubercular is apparently also rather of the lacinate type, possessing "a nearly median cusp in front, which is joined to the low one on the internal border of the crown." It is not known whether M_3 was present. In the skull of *Enhydrocyon* the single pair of postparietal foramina are larger but are apparently situated much as the poste-

[27] E. D. Cope. Tertiary Vertebrata, p. 938. Also, *ibid*, "The heel of the sectorial is cutting, as in *Temnocyon*." . . .

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rior pair in *Philotrox*. The otic bullae in both genera are extraordinarily large.

Tomarctus Cope from the Loup Fork Miocene of Colorado is evidently a more specialized form, both as regards the reduction of the premolars and the development of M_1.

Philotrox resembles the Old World Simocyonines in the shortness of the jaw, and the rather heavy type of the premolars. It differs from *Simocyon* in the greater development of P_2 and P_3, in the much smaller size of M_2, and in the presence of M_3. The heel of M_1 is also less distinctly basin-shaped in *Philotrox*. From *Cephalogale* it is distinguished by the absence of P_1 and the greater development of P_2 and P_3. The cusps of the lower carnassial are also somewhat more elevated and the metaconid seems to be less prominent. In other respects there is much in common with *Cephalogale*, particularly in M_2 and M_3, and in the form of the heel of M_1.

Of the five genera referred to the Simocyoninae all are removed from *Philotrox* by quite a distance. *Cephalogale* is possibly one of the nearest, while *Simocyon* is one of the farthest removed. *Oligobunis* is evidently not closely related; *Enhydrocyon* and *Hyaenocyon* appear to be about as far removed as *Oligobunis,* but are not well enough known to warrant a definite statement.

In the present state of our knowledge it is difficult to determine exactly the relative stages of evolution reached by the John Day types of short-faced dogs. *Philotrox* does not appear to represent either the most primitive or the most specialized type of the four genera. As far as is known, it seems to show a somewhat higher development of the crushing functions in the tubercular region of the inferior molars than we find in the other forms.

It is also difficult to make even a tentative statement as to the probable origin of *Philotrox*. While it exhibits some resemblance to *Cephalogale,* it is to be doubted whether its affinity in this direction is really closer than with some of the members of the *Cynodictis* group. Particularly is this true of the cusps of the inferior sectorial which are hardly of the type of *Cephalogale*. I

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am inclined to accept the suggestion of Wortman[28] that a member of the White River genus *Daphaenus,* like *D. dodgei,* may lead to some of the short-jawed dogs of the John Day. The evidence of relationship to this form seems at least as strong in the case of *Philotrox* as in any of the other genera. *D. dodgei* has a rather short, heavy jaw. Excepting P_1, which is much reduced, the premolars are heavy, and possess posterior cusps. The heel of M_1 is broad and basin-shaped, the form and arrangement of its three tubercles appearing to be much the same as in *Philotrox.*

So great is the diversity of form among the four genera of short-faced John Day dogs that it is difficult to determine from the material available whether we are warranted in considering them all as descendants of the same stock. If such similarities as they show are actually an expression of common ancestry, it would seem that we find at least as many of the necessary characters of this ancestral type in the North American *Daphaenus,* as in *Cephalogale* or in any of the European genera.

The relationships of the previously known short-faced John Day dogs to the European Simocyonines seem in a general way to be far from close. The affinity with *Cephalogale* is presumably not as close as with *Daphaenus.* Compared with *Simocyon,* we find the dentition differing in each genus about as widely as it could be made to differ and still keep them short-faced, heavy-toothed canids. No single functional cheek tooth of *Simocyon* shows much resemblance to the corresponding tooth of *Oligobunis.* This would be true also of the inferior cheek teeth and upper carnassial of *Enhydrocyon.* The upper molars of *Enhydrocyon* are too imperfectly known for comparison. In *Hyaenocyon* the inferior cheek teeth are different, as far as known. The superior sectorial suggests a structure somewhat similar to that of *Simocyon,* but M_1 is much smaller and there was no second superior tubercular.

It is to be expected that differentiation will tend to produce short-faced, heavy-toothed carnivores of the hyaenoid type as often and in as many places as circumstances will permit. The Hyaenidae represent an Old World adaptation in this direction. They have come to differ so far from the other groups of the

[28] J. L. Wortman. Am. Jour. Science, June, 1901, Vol. XI, p. 449.

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Carnivora Vera and to fill such an important place in eastern Arctogaea that they are separated as a distinct family. Whatever the ancestors of the hyaenas may have been, they were probably not true canids. A somewhat similar adaptation has occurred in the Canidae. So similar have the results been in the two cases, as far as function and superficial characters are concerned, that several canids from the American faunas have found temporary location with the hyaena group in the classification.

It appears more than probable that the development of hyaenoid characters in the Canidae has gone forward to a great extent independently in North America and Europe, and has, moreover, produced quite different results in the two regions. It is not improbable that there has been mixing of the resultant types through migrations, though we have as yet little evidence of such intermigration. Unless we can discover more definite evidence of common descent of the American and European genera than has yet been brought forward, it must appear that the sub-family Simocyoninae as generally accepted, including *Simocyon, Cephalogale, Oligobunis, Enhydrocyon,* and *Hyaenocyon,* is a group of polyphyletic origin, representing a general type of adaptation rather than similar characters expressive of common origin. At the present time we are not even in a position to state definitely that all of the genera mentioned are really typical canids. The continuance of their definite arrangement in one sub-family will serve only to cover up certain weak places in our phylogenies, and ultimately to impede the progress of knowledge.

MEASUREMENTS.

	mm.
Length, anterior side of inferior canine to posterior side of M_1	63
Length, posterior side of inferior canine to posterior side of P_4	35.5
Height of mandible below middle of P_2	21.5
Height of mandible below protoconid of M_1	19.5
I_2 (?), transverse diameter	2.8
I_3, transverse diameter	4
Inferior canine, length from unworn tip to alveolar border	21.5
Inferior canine, greatest antero-posterior diameter at base	10.5
P_2, antero-posterior diameter	8.3
P_2, transverse diameter	5.2
P_3, antero-posterior diameter	10.5
P_4, antero-posterior diameter	11.6

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P_4, transverse diameter	6.5
M_1, antero-posterior diameter	18.0
M_1, transverse diameter of trigonid	7.8
M_1, antero-posterior diameter of heel	5
M_1, transverse diameter of heel	7.1
M_2, antero-posterior diameter	8
M_2, transverse diameter	5.4
M_3, antero-posterior diameter	*a* 5
Height of inion above foramen magnum	33
Greatest width across occipital condyles	34.5
Height of foramen magnum	12
Greatest antero-posterior diameter of otic bulla	28.5
Greatest transverse diameter of otic bulla	19

a. Approximate.

FELIDAE.

Though fairly well known from skulls and teeth, the John Day cats have, as a whole, presented some of the most puzzling features of this fauna. The most common and best known forms included in the genera *Archaelurus* and *Nimravus* have been generally considered as representing the most primitive division of the machaerodont group of the Felidae. In the White River beds, held to be older than the John Day, there appeared to be among the felines no forms so primitive as these. As the other elements of the John Day fauna are nearly all more advanced than the corresponding forms of the White River, the evidence regarding the age of the beds which is furnished by these cats seemed to contradict that of the remainder of the fauna.

Much yet remains to be learned concerning the John Day cats, as in most cases but little excepting the skull and dentition has been discovered.

No representatives of the Felidae have been described from the Mascall beds.

The following species are known from the John Day series:—

Archaelurus debilis Cope.
Nimravus gomphodus Cope.
Nimravus confertus Cope.
Deinictis cyclops Cope.
Pogonodon platycopis Cope.
Pogonodon brachyops Cope.
Pogonodon davisi, n. sp.
Hoplophoneus cerebralis Cope.
Hoplophoneus strigidens Cope (?).

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NIMRAVUS AND ARCHAELURUS.

Pl. 4; Pl. 5, Figs. 1 and 2; and Text-figure 16.

Generic and Specific Distinctions. The genera *Archaelurus*[29] and *Nimravus*[30] were established by Cope to include three feline species related to the sabre-tooth forms but having very primitive characters. They were referred to by Cope as the "false sabre-tooths," owing to their lack of a prominent flange on the antero-inferior angle of the lower jaw, and the absence of a cutting edge on the anterior side of the relatively short upper canines. There was also noticed in both genera a peculiar exostosis or a thickening of the outer side of the alveolar border immediately below the inferior molars. Neither genus was known outside the limits of the John Day series. Of the two, *Archaelurus* was said to be the more primitive, having one more premolar in each jaw, and smooth-edged instead of posteriorly serrated upper and lower canines. Other differences between the single species of *Archaelurus* and the two placed in *Nimravus* were supposedly of no more than specific value.

Though *Archaelurus* and *Nimravus* appeared to Cope to be quite distinctly separated, studies of recently discovered material show that they are scarcely separable if not identical generic types. In the University of California collections there are several specimens which show the skull and dentition of forms belonging in this group more perfectly in some particulars than they were exhibited in the types.[31] All of this material indicates that *Archaelurus* is not so distinctly separated from *Nimravus* as it was considered to be by Cope.

In a particularly well-preserved skull (No. 1681), pl. 4, and text-figure 15, there is a mixture of the characters of *Archae-*

[29] *Archaelurus.* Am. Nat., Vol. 13, Dec. 4, 1879, p. 798*a*-798*b*.

[30] *Nimravus.* Proc. Acad. Nat. Sc., Philad., Aug. 12, 1879, pp. 169 and 174.

[31] This material includes the following specimens: No. 1681, perfect cranium without mandible, with axis and one other cervical vertebra; No. 1685, cranium with dentition, lacking I^1 and the frontal region; No. 1679, mandible with dentition; No. 1680, middle portion of mandible with P_3 and M_1, also five lumbar vertebrae; No. 1683, half of mandible with M_2 and parts of other teeth; No. 2256, nearly complete hind limb; No. 110, perfect tibia, calcaneum, fragments of metapodials, caudal vertebrae. In addition to these there are a number of loose teeth and scattered limb bones.

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lurus and *Nimravus*. As in *Archaelurus debilis*, there are four superior premolars. The upper canine is slightly shorter and appears to show a little more curvature than in *Nimravus*, but in other characters it differs greatly from *Archaelurus* as described, and in these particulars resembles *Nimravus*. The posterior side instead of being smooth-edged is strongly compressed and has a sharply serrated margin. As in *Nimravus*, the anterior side is broad, and is slightly concave toward the inner

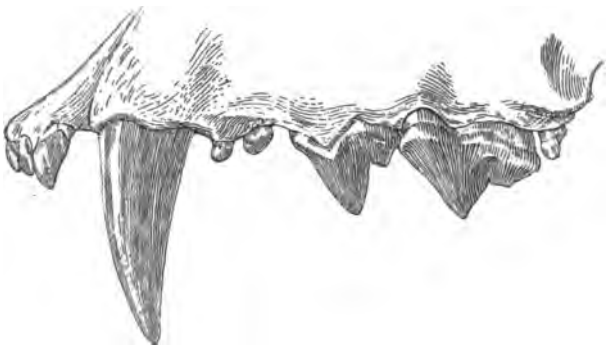

Fig. 15. *Archaelurus debilis major*. No. 1681. Middle John Day, Logan Butte, Crook County, Oregon. × ¾.

angle. The outer anterior portion is rounded. The inner anterior angle is acute, and is noticeably serrated toward the base of the tooth. In this last character it is even more specialized than the corresponding portion of this tooth as described for *N. gomphodus*. The skull in which this dentition occurs represents an individual much larger than the type of *A. debilis*. In dimensions it is nearest to the type of *N. gomphodus*, the largest described form referred to either of these genera, but it exceeds this specimen in axial length by about 20 millimeters.[32]

It is difficult to determine the affinities of this form, judging solely from the characteristics which appeared in the type specimens. As the form represented by specimen No. 1681 is separated from *Archaelurus* principally by the character of the margins of the superior canine, the writer has examined the type

[32] Axial length of skull. Type *A. debilis*, 180 mm. Type *N. gomphodus*, 206 mm.; No. 1681, 225 mm.

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specimen of *Arehaelurus* with a view to verifying Cope's statement regarding this tooth. It was found, however, that the posterior margins are really serrated instead of smooth, Cope having been deceived apparently by the worn surfaces of the tooth. The anterior sides were so much worn that it was not possible to determine their exact form. The evidence available seems to me to indicate that no sufficient generic distinctions are to be obtained in the character of the canines. Though slight differences in the structure of the margins may exist, it is very doubtful whether such variations in general form as may be present are of more than specific value.

As to the other generic character used by Cope, namely, that based upon the number of premolars, Cope's type of *N. gomphodus* shows no indication of the presence of premolar one in either the upper or the lower jaw, but as this tooth is exceedingly small in *Archaelurus* it is easily conceivable that it would disappear in many cases. In the collection of Professor Thomas Condon, at the University of Oregon, there is a well-preserved feline skull which was studied by Cope and was labeled *N. gomphodus* by him. In this individual there are but two inferior premolars. In the specimen as it was studied by Cope there appeared to be only three upper premolars, but more careful preparation of the upper jaw has shown an alveolus for a fourth, or P^1. In whichever genus this species is placed the dentition of one jaw will represent the other genus.[33]

The differences between the types of *Archaelurus* and *Nimravus*, or *A. debilis* and *N. gomphodus*, are perhaps most strongly expressed in the lower jaws. In Cope's material, *A. debilis* was characterized by the presence of a very large exostosis below the molars, while in *N. gomphodus* this was represented by only a slight swelling of the external alveolar border. According to Cope, this thickening was "larger in some specimens than in others." *N. gomphodus* was supposed to be further characterized by the absence of P_2, absence of an anterior basal tubercle on P_3, and the failure of the massateric fossa to reach the inferior border of the ramus at any point.

[33] Judging from Condon's figures (The Two Islands, Pl. 20, opposite p. 124), the superior canine and mandible are of the *Archaelurus* type.

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As in the crania described above, the mandibles in the University collections all show more or less mixing of characters. A large specimen (No. 1679, text-figure 16) exceeds the type of *A.*

Fig. 16. *Archaelurus debilis major.* No. 1679. Middle John Day, Blue Basin, Turtle Cove, John Day Valley, Oregon. × ½.

debilis in size by about 30 per cent. Its dimensions are in general near those of the type of *N. gomphodus,* but it is even larger than that form, and apparently represents the largest known individual of this group. The exostosis is intermediate in size between the slight thickening in *N. gomphodus* and the greatly inflated alveolar border of *A. debilis.* The massateric region is similar to that of *Archaelurus,* but the mandible is relatively higher below the diastema than in the type specimen. The posterior angle of the canine is denticulate, as in *Nimravus.* P_2 is double-rooted instead of single-rooted as described for *Archaelurus* by Cope, but a reëxamination of the type shows that it is two-rooted there also. P_3 possesses a small anterior basal tubercle as in *Archaelurus.*

In another specimen (No. 1680), representing the median portion of the jaw, the inferior canine, and several lumbar vertebrae, the dimensions are intermediate between those of *A. debilis* and the large specimen described above. The exostosis is little if any larger than in *Nimravus,* and the canine shows posterior serration, but the massateric region is apparently as in *Archaelurus.* The height of the jaw seems to be relatively less than in the

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larger specimen. As in *Archaelurus,* P_2 is double-rooted and P_3 has a weak anterior basal tubercle.

A third and much smaller mandible (No. 1683) shows the weak exostosis of *N. gomphodus* and the double-rooted P_2 of *Archaelurus.* The inferior portion of the jaw is broken away, but the massateric fossa extends far forward as in *A. debilis.* In this specimen the diastema, to P_2, is very short and the median portion of the inferior side of the symphyseal region is rather prominent. The well-preserved M_2 is laterally compressed and has a divided root. It shows a sub-acute superior ridge which is divided into a median tubercle and distinct anterior and posterior basal ridges.

The relative dimensions of these individuals compared with those of the described species of *Archaelurus* and *Nimravus* are brought out in the following table:—

	N. gomphodus type	No. 1679	No. 1680	*A. debilis* type	No. 1683	*N. convertus* type
Length of mandible, anterior side of symphysis to posterior side of condyle	158	*a*175	.....	140	.....	.....
Height of mandible below middle of diastema	27	31	.....	20	20	20
Height of mandible at posterior end of P_4	31.5	37	.....	24	.....	.....
Length, posterior side of canine to anterior side of P_2	.....	16	.....	14.5	10	.....
Length, posterior side of canine to anterior side of P_3	23	25	.....	21	18.5	12.5
Antero-posterior diameter of P_3	17	17	15	14	.....	13.3
Antero-posterior diameter of P_4	20	19.5	.....	15	.....	16
Antero-posterior diameter of M_1	25	27	26	.....	.....	22.5

a Approximate.

The mandibles described above correspond generically to *Archaelurus* and differ from the two species of *Nimravus* in the presence of P_2 and in the characters of the massateric fossa. In the two specimens in which P_3 is present it supports an anterior basal tubercle as in *Archaelurus.* In each individual, however, some considerable deviation from the type of *Archaelurus* is seen, and in all cases this variation is toward the type of *Nimravus.*

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Specifically the individuals described above are not readily fitted into any of the known groups. The largest specimen, No. 1679, exceeding both *A. debilis* and *N. gomphodus* in size, belonged to an individual slightly larger than that represented by the skull No. 1681 described above (p. 39). These two specimens probably represent the same species, which is possibly a variety of *A. debilis,* or as suggested by the size and by the reduction of the exostosis, it is perhaps a variant from the *N. gomphodus* type. Until more is known of the variation in the group this form may be tentatively known as *Archaelurus debilis major.*

The slightly smaller mandible, No. 1680, corresponds closely to *N. gomphodus* in size, and possesses only a rudimentary exostosis. As P_2 was present and P_3 has an anterior basal tubercle, this specimen may be tentatively referred to *A. debilis major.*

The third specimen, No. 1683, has nearly the same dimensions as the type of *A. debilis,* and is referred to that species, though as in *N. gomphodus* the inferior portion of the symphyseal region is prominent and the exostosis much reduced.

The great variation in size and form of the exostosis among these and other known specimens indicates that, as suspected by Cope, this structure cannot be used in generic separation and only doubtfully in distinction of the species. The value of the anterior basal tubercle on P_3 in separating the genera must also be doubtful, as the difference between the small anterior tubercle in *Archaelurus* and the rather prominent anterior basal angle in *Nimravus* is slight. The presence of P_2 in *A. debilis* is of doubtful value as a distinguishing character. It is a very small and practically functionless tooth, and its occurrence would naturally be variable. While it is usually present in specimens with the *A. debilis* type of massateric fossa and showing an anterior basal tubercle on P_3, it is also associated with a posteriorly serrated inferior canine and a greatly reduced exostosis. It is absent from Professor Condon's specimen in which the superior premolar dentition is that of *Archaelurus.* Practically the only character which seems distinctive is found in the form and size of the massateric fossa. In *N. gomphodus* its inferior margin is separated from the lower border of the horizontal ramus by a wide bar. In *A. debilis* the fossa extends farther forward and

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reaches down to the inferior margin of the jaw, which it may follow for some distance.

In the present state of our knowledge there appear to be three or four types represented in the *Archaelurus-Nimravus* group. It is not certain that they represent distinct species and the number will possibly be reduced when more material is known.

A. debilis is a small form representing the more primitive extreme in premolar dentition and possibly in the form of the canines. P_3 has an anterior tubercle. The massateric fossa is relatively broad and the exostosis is large. The type skull is 180 mm. long, P^1 and P_2 are both present, the canine is not greatly elongated. It represents a fully adult individual and possibly a female.

A. debilis major. Large forms with variable premolar formula, reduced exostosis, and wide massateric fossa. Superior canines moderately elongated, with serrated posterior edge, and with basal anterior groove. Type skull No. 1681 (pl. 4), a young individual; basal length 225 mm. Mandible No. 1679 (text-figure 16), referred to this species, is from a somewhat larger individual with teeth but little worn. The inferior canine has a serrated posterior margin, P_2 is two-rooted, P_3 with anterior basal tubercle, and the exostosis is somewhat reduced. These two young specimens exceed the old individual representing the type of *debilis* by more than 45 mm. in skull length, which is more than the ordinary range of sexual variation in cat skulls of approximately this size.

N. gomphodus has a generally reduced premolar dentition, lacking both P^1 and P_2. The canines are relatively long and slender, though both characters are doubtless somewhat exaggerated in the type specimen. P_3 without distinct anterior basal tubercle. Massateric fossa relatively narrow. The skull characters separating this species from *A. debilis* are largely bridged over by *A. debilis major.*

N. confertus resembled *N. gomphodus* excepting in the character of the greatly shortened inferior diastema. Known only from the lower jaw.

The observations presented above indicate some of the difficulties met in attempting to carry a separation of the generic

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groups *Archaelurus* and *Nimravus* beyond the type material. It should be stated further that a somewhat similar mingling of characters of these genera is encountered in a study of the structure of the skull, limbs, and vertebrae. As far as is known, nearly all the supposed diagnostic characters seem to be variable and untrustworthy, excepting possibly the form of the massateric fossa, and it is doubtful whether more than specific value attaches to this feature. The group as a whole seems to show much individual variation, and under these circumstances a thoroughly satisfactory arrangement of the species and genera can be accomplished only by the study of much larger collections than are now available. Cope's collection seems to have contained in the types of *A. debilis* and *N. gomphodus* two rather extreme variants. Neither of these extremes has been met outside of the type collection. Although the larger part of the known material is not included in Cope's collections, all of the specimens range between the limits of these two forms.

Collectively the forms in the *Nimravus-Archaelurus* group represent a fairly distinct feline type. They are characterized in skull and dentition by the absence of a prominent flange on the antero-inferior angle of the mandible; a tedency toward full representation of the premolars; absence of deuterocone on P^4, of protocone on M^1, and of metaconid on M_1; incomplete development of the anterior cutting edge on the superior canines; the presence of a small M_2 and of a peculiar exostosis on the external alveolar margin adjacent to it; and the slight inferior projection of the posttympanic process and of the root of the zygomatic process of the squamosal. This group corresponds in rank to the average genus and, unless further additions to the available material should bring out more definite distinguishing characters, the later name, *Archaelurus,* will probably be ultimately eliminated.

As has been recognized particularly by Adams,[34] the members of the *Nimravus-Archaelurus* group show strong resemblances in dental and cranial characters to *Ailurictis* of the European Oligocene and, as indicated below (p. 50) under the discussion of the extremities, this similarity extends also to the limb structure.

[34] G. I. Adams. Extinct Felidae., Am. Jour. Sc., 1897, Vol. 154, p. 146.

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There are still a number of characters separating them which may as a whole distinguish the groups sufficiently to permit our continuing them as distinct genera. *Ailurictis* appears, however, to be closely related to the American genera and to represent the same division of the Felidae.

MEASUREMENTS.

Skull of *Archaelurus debilis major*, No. 1681.	mm.
Axial length from anterior side of premaxillae to posterior side of occipital condyles	225
Axial length from anterior side of premaxillae to anterior side of inferior narial openings	87
Greatest width across zygomatic arches	150
Width of palate between inner roots of P^4	56
Height of inion above foramen magnum	39
Height of antero-inferior side of orbit above alveolar border at P^4	36
Length, anterior side of superior canine to posterior side of M^1	81.5
Length, anterior side of P^3 to posterior side of M^1	48
Superior canine, length, tip to alveolar border on incompletely erupted tooth	38
Superior canine, antero-posterior diameter at base	16.5
Superior canine, transverse diameter at base	9.2
P^2, antero-posterior diameter	3.9
P^3, antero-posterior diameter	6.6
P^3, antero-posterior diameter	20.5
P^4, antero-posterior diameter	24
P^4, transverse diameter across inner root	15
M^1, antero-posterior diameter	5.7
M^1, transverse diameter	8

Limbs.—Several specimens in the University collection show considerable parts of the appendicular skeleton of feline forms which are very near *Archaelurus*. Among these there is a hind limb, No. 2256 (pl. 5, fig. 1), lacking only the terminal phalanges. This furnishes for the first time sufficient material for satisfactorily determining the foot structure in this group. The specimen evidently represents a form close to *A. debilis*, though somewhat larger. It is here tentatively referred to *A. debilis major*.

The femur is much like that of *Nimravus gomphodus* as described by Cope.[35] It differs from this type in that there is no groove connecting the shallow pit for the round ligament with

[35] Tert. Vert., p. 970, Pl. 74, Fig. 2.

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the neck. Unfortunately the femur of *Archaelurus debilis* was not known to Cope.

The tibia is similar to that described for *A. debilis*, excepting for its larger size, and that there are two grooves for the tendons passing over the posterior side of the internal malleolus on this specimen as in existing felines. This is also the case in another and more nearly perfect tibia (No. 110, pl. 5, fig. 2) showing also the characters of *Archaelurus*. In the type of *A. debilis* there is stated to be but one groove.

The astragalus duplicates the peculiar structure seen in *A. debilis*, having a very short neck and a rather long inner border of the trochlea. The internal trochlear ridge is separated a little farther from the distal end of the neck than in *A. debilis*, but a series of otherwise similar specimens of this type shows a slight variation in this character. As has been suggested by Scott,[36] a small facet on the external side of the distal end of the neck corresponds in position to the cuboid facet of the Ursidae. This facet is, however, continuous with the surface of articulation for the sustentaculum and its articulation probably did not reach beyond the calcaneum. The cuboid articulates closely with a distinct facet near the distal end of the external face of the ectocuneiform, and is not higher than the ectocuneiform and navicular as it is in the bears. It shows, moreover, no facet for articulation with the astragalus.

The calcaneum exhibits a strongly marked fossa external to the outer astragalar facet somewhat similar to that seen in *Pogonodon brachyops*, though not so deep as in that form. The sustentacular facet is very long, reaching forward to the extreme anterior end of the bone. Separated from the anterior end of this facet by a sharp angle is a small face in articulation with the navicular. In specimen No. 110 the fossa external to the outer astragular facet is deeper and the sustentacular facet shows a slight median interruption.

The navicular is considerably produced posteriorly, as was suggested by Cope from his study of the navicular facet of the astragalus. In this specimen the outer side bears a distinctive

[36] W. B. Scott. Osteology of Dinictis felina., Proc. Philad. Acad., July 30, 1889, p. 226.

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mark in the presence of a deep pit opposite the middle of the astragalar facet. The cuboid is a little higher than wide and shows a deep peroneal groove. The mesocuneiform and entocuneiform are small and narrow.

The form of the metatarsals shows the foot to be more specialized than might have been inferred from a study of the skull and dentition. Compared with the size of the tarsus, the middle metatarsal is long and relatively heavy. The total length of the tarsus, measured to the posterior end of the calcaneum, is a little less than that of metatarsal three. In most felines, particularly in the older forms, the tarsus is considerably longer than the metatarsus. This is particularly noticeable in *Hoplophoneus* and to a less extent in *Deinictis*.

The lateral digits are relatively reduced. Metatarsal three is considerably larger and heavier than the others, while number five is relatively short and slender. Number two is also considerably reduced. The proximal end of number two has been somewhat damaged, so that it is not possible to determine certainly whether the foot retained a part of metatarsal one. A small depression on the median or free side of the proximal end of this element, but scarcely reaching beyond the proximal end of metatarsal three, may have been occupied by a rudimentary metatarsal one. As the distal end of the entocuneiform is very thin and slender, such a rudiment if present at all must have been very small.

The reduction of the lateral digits is greater than that in *Deinictis* and *Hoplophoneus*, or than in many of the typical modern cats. A somewhat similar relative elongation of the middle metatarsals and reduction of the lateral ones is seen in the cheetah and caracal.

A slenderness of the anterior foot is indicated by Cope's statement[37] that the fifth metacarpal was relatively much smaller than in the typical modern Felidae.

The terminal phalanges are not known in association with other determinable skeletal elements. The other phalanges are rather broad. The middle phalanx in each digit shows considerably less oblique excavation of the shaft on the outer side than

[37] Tert. Vert., p. 961.

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is seen in the modern Felidae with strongly developed retracile terminal phalanges.

Of the relative length of the whole limb no very definite estimate can be made, as complete limb segments have not been found associated with the skull or vertebrae. Comparative measurements of the specimen in which the pes is present with broken tibia and femur (No. 2256), and of No. 110, with complete tibia and calcaneum, indicate that the tibia was a little shorter than the complete pes. An approximation of the proportions in *Archaelurus* compared with those of *Deinictis* seems to show that the tibia has about the same relative proportion to the skull length in the two forms. Compared to the length of the tibia, the combined lengths of the tarsus and metatarsus appear to be a little greater in *Archaelurus*. The relatively long middle metapodials, the reduced lateral metapodials, and the relatively long tibia point toward a type of limb like that seen in the cheetah or hunting leopard rather than toward the type of the lion or tiger. It is also interesting to note that in the loss of the deuterocone of P^4, and in the relative strength of the middle premolars the dentition shows the same resemblances.

In his admirable discussion of the White River sabre-tooths, Dr. W. D. Matthew[38] has suggested that we may . . . "explain the apparent conservatism in the *Deinictis* dentition by the assumption that its prey consisted in greater part of the smaller, speedier animals of the plains, which it must run down by superior speed or endurance, while the *Hoplophoneus* preyed more on the larger, slower animals of the plains or forest, whose destruction required a more powerful animal with more effective weapons of attack." This suggestion will, I believe, account for the persistence in the John Day of a type like *Archaelurus* with certain apparently primitive characters in its dentition. The greater the specialization of the feet for running, the less useful would they be for grasping, and the less would be the value of greatly elongated superior canines. The presence of long, knife-like canines is correlated with powerful grasping feet possessing highly developed retractile claws. With its powerful feet the animal clung to its prey while it struck repeatedly with its thin,

[38] Mem. Amer. Mus. Nat. Hist., Vol. I, Part 7, p. 394.

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sharp sabres. When the canines are not developed to the dagger-like form for stabbing, the premolar teeth serve a more definite purpose in the destruction of prey, and would be less subject to reduction.

The view suggested above finds support, in that such evidence as we have indicates that during the deposition of the Middle John Day beds this region was in the main a country of open plains, offering advantages to running types of carnivores, and that during this epoch the *Archaelurus-Nimravus* type of feline was by far the most common form.

As might be surmised from the known similarities in cranial and dental characters, the foot structure of *Archaelurus* shows considerable resemblance to that in the genus *Ailurictis* of the European Oligocene. As has been shown by Schlosser,[39] metatarsal one is greatly reduced in *Ailurictis*, and particularly the middle metapodials are rather heavy. These characters, as also the unusual elongation of the proximal, external tubercle on metatarsal five, are distinctive features of *Archaelurus*. The limb structure differs somewhat in the two groups in that metatarsals two and five are somewhat less reduced in *Ailurictis*, and the astragalus is stated to show close resemblance to that of *Felis*, while in *Archaelurus* this element has a different and quite distinctive form. As far as can be determined, *Archaelurus* seems slightly more advanced than *Ailurictis* in foot structure.

MEASUREMENTS.

A. debilis major, No. 2256.

	mm.
Femur,[40] antero-posterior diameter of head	22.8
Femur, transverse diameter of shaft near middle	22
Femur, transverse diameter of distal end	50.5
Femur, width of rotular face at middle	18
Tibia, transverse diameter at distal end	33.5
Tibia, transverse diameter at proximal end	48
Tibia, antero-posterior diameter at proximal end	52
Calcaneum, greatest antero-posterior diameter	67

[39] M. Schlosser. Beiträge zur Palaeont. Oestr-Ung., B. 6, p. 431.

[40] The shaft of the bone has been shattered in the femur and tibia so that the length could not be accurately determined in this specimen.

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Astragalus, greatest antero-posterior diameter	36
Astragalus, antero-posterior diameter through trochlear region	28.3
Astragalus, greatest width of trochlear surface	20
Cuboid, greatest antero-posterior diameter on superior surface	17
Combined antero-posterior diameter of calcaneum and cuboid in position	82
Width of tarsus, cuboid, and navicular	35
Metatarsal III, greatest length from distal end to ectocuneiform articulation measured on superior surface	85.7
Metatarsal III, transverse diameter at narrowest portion of the shaft	13.8
Metatarsal IV, greatest length from distal end to cuboid ariculation measured on superior surface	82
Metatarsal IV, transverse diameter at narrowest portion of shaft	10.5
Metatarsal V, greatest length from distal end to cuboid articulation measured on superior surface	65
Metatarsal V, transverse diameter at narrowest portion of the shaft	8

In another specimen, *A. debilis major* (No. 110) showing the same characters as those found in that described above, the perfect tibia and calcaneum have the following dimensions:—

	mm.
Tibia, greatest length	256
Tibia, transverse diameter at proximal end	53
Tibia, antero-posterior diameter at proximal end	55.5
Tibia, transverse diameter at distal end	37
Calcaneum, greatest antero-posterior diameter	70

Vertebrae.—With the *Archaelurus* skull No. 1681 there are preserved the axis and the third cervical. Both are much like the corresponding elements described by Cope for *Nimravus gomphodus*, and no characters are noted which would serve to distinguish them.

Associated with the lower jaw No. 1680, referred to *A. debilis major*, there is in the collections from the Middle John Day a series of four posterior lumbar vertebrae in articulation. The anterior member of the series supports a very sharp, thin, inferior keel, and the metapophyses are narrow. There is a rudimentary anapophysis on this vertebra and the succeeding one. The spine and transverse process are broken away. On the third member of the series (text-figure 17) the inferior keel is strong, but not

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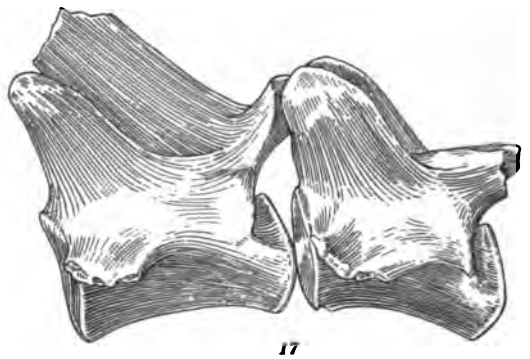
as thin as on the first, and there is a minute rudiment of an anapophysis on one side only. The neural spine is rather broad and high, but is unfortunately not complete. The fourth vertebra is shorter than the others, the metapophyses are broader, the inferior surface is not distinctly keeled, and the thin transverse processes are well developed though broken distally. This verte-



17

18

Fig. 17. *Archaelurus debilis major.* Lumbar vertebrae. No. 1680. Middle John Day, Turtle Cove, John Day Valley, Oregon. × ¾.

Fig. 18. *Archaelurus debilis major.* Caudal vertebra. No. 110. Middle John Day, Blue Basin, John Day Valley, Oregon. × ¾.

bra is peculiar in that it lacks a neural spine. In the place of the spine there is a very indistinct ridge not exceeding a millimeter in height. This last vertebra is presumably the seventh lumbar, the others being the sixth, fifth, and fourth. This vertebra does not agree in form with the seventh lumbar of *Archaelurus debilis* described by Cope, which had a high neural spine.

With the complete tibia and calcaneum, No. 110, referred to *Archaelurus,* there is a large but slender caudal vertebra (text-figure 18) which must have been situated near the middle of a long slender tail.

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MEASUREMENTS.

Vertebrae, associated with type skull of *A. debilis major*, No. 1681.

	mm.
Axis, length of centrum including odontoid process	53
Axis, antero-posterior length of neural arch, approximate	54
Axis, height from middle of inferior side of centrum to top of neural arch	43
Third cervical, length of inferior side of centrum	22
Third cervical, width across postzygapophyses	33
No. 1680, associated with lower jaw of *A. debilis major* (?).	
Fourth lumbar, length of centrum	40
Fourth lumbar, width of posterior end of centrum	28
Fourth lumbar, height of posterior end of centrum	19
Fifth lumbar, length of centrum	41
Fifth lumbar, width across posterior zygapophyses	24
Sixth lumbar, length of centrum	40.5
Sixth lumbar, width of posterior end of centrum	29
Sixth lumbar, height of posterior end of centrum	19
Sixth lumbar, height of neural spine above lower side of neural canal, approximate	48
Seventh lumbar, length of centrum	38
Seventh lumbar, width of posterior end of centrum	31
Seventh lumbar, height of posterior end of centrum	19
Seventh lumbar, width across metapophyses	33.5
No. 110, associated with *Archaelurus* type of tibia and calcaneum.	
Caudal, length	53
Caudal, transverse diameter at narrowest point	14.7
Caudal, height of posterior end of centrum	15

POGONODON DAVISI, n. sp.

Pl. 6, Figs. 1, 2, and 3.

No. 789, Univ. Calif. Col. Vert. Palae. From the Upper John Day, five miles southeast of Monument, Grant County, Oregon.

Distinctive Characters.—Skull large, sagittal crest very high and thin, brain case small. Dentition $\frac{3}{3}, \frac{1}{1}, \frac{3}{3}, \frac{1}{1}$. Third upper incisor relatively large. Upper canines large but not greatly compressed laterally. P^2 very small, one-rooted. P^4 without deuterocone, with incipient protostyle, not exceeding the superior canine in antero-posterior diameter. M^1 small, narrow transversely, without distinct internal or protocone lobe.

The type specimen, a skull without mandible, was found in the Upper John Day beds, southeast of Monument, Oregon, by

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Mr. Leander S. Davis, whose efficient services as guide and collector I take pleasure in recognizing in this connection.

Cranium.—The size of the skull places this form among the larger and more powerful John Day carnivores. The cranium is characterized particularly by the very high and thin sagittal crest, which is so strongly elevated that the highest point on the skull is thrown extraordinarily far back. The brain case is small and the thin crest rises quite abruptly above it. The parietal foramina are situated low down on the base of the crest, but on the left side there is an additional foramen higher up on the side. The occiput is high and narrow, its width a little below the middle being less than that near the upper end. The lower portion is evenly rounded but not keeled, the upper portion is gently concave. A faint median keel and two lateral ones arise near the upper end, but no strong or persistent keel is present on the occiput. The zygomatic arches are widely spread. The root of the zygomatic process of the temporal is not lowered below the level of the basisphenoid as in *Hoplophoneus*. The glenoid fossa is in nearly the same plane with the inferior surface of the basisphenoid, but is not below it, and there is no apparent tendency toward the development of an inferior pedicle for the support of the jaws such as is seen in the typical sabre-tooths. The posttympanic process extends below the plane of the paroccipital process, but is not more strongly produced inferiorly or more closely approximated to the postglenoid than in *Pogonodon brachyops*.

The facial region is flattened and somewhat depressed immediately in front of the orbits, and the nasals are not prominent. The superior extensions of the premaxillaries reach backward a considerable distance, but do not meet the frontals. The nasals extend backward to a point a little behind the narrowest space between the superior margins of the orbits and considerably posterior to the highest point of the maxillaries. Immediately behind the union of the fronto-maxillary and fronta-nasal sutures the nasals are slightly widened. The postorbital processes are prominent and the frontal region is relatively wide. The fronto-maxillary suture extends upward from the border of the orbit and then turns forward nearly horizontally before bending downward to the nasal suture, leaving the frontal with a very small

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and narrow nasal process. Though not entirely similar, the relations of this suture are somewhat like those of *Deinictis.*

The palate is broad posteriorly and the inferior hares reach forward almost to the molars. The posterior palatine foramina are nearly opposite the anterior border of P^3.

The foramina of the basi-cranial region of the skull are much like those of *Nimravus* and *Deinictis.* The alisphenoid canal and foramen ovale are in a shallow depression near the glenoid fossa. The carotid canal and foramen lacerum posterium appear to be separated.

Dentition.—The anterior ends of the premaxillaries are broken away, leaving only portions of the roots of the incisors. I^1 is small and I^3 very large. The canines are absent, but their alveolar walls are well preserved, giving the approximate dimensions of these teeth at the base. Compared with the sectorials, the antero-posterior diameter is relatively larger than in *Deinictis,* and approaches more nearly the size seen in *Hoplophoneus.* The transverse diameter seems to indicate something less than the degree of compression shown in the canines of most species of *Hoplophoneus.* P^2 was very small and had but one root. P^3 is relatively smaller than in *Deinictis.* In addition to the large posterior cusp, there is present a minute tubercle situated on the inner side of the anterior border. The superior sectorial does not possess a distinct deuterocone, though the inner root is moderately developed. Somewhat above the basal end of the sharp anterior edge of the protocone on the right sectorial there is a faint but distinct notch separating an incipient protostyle. The anterior border of the left sectorial is somewhat worn, but shows traces of a similar notch on the worn edge, though it was evidently weaker than on the other sectorial. Though the incipient protostyle occupies the same position as in *Hoplophoneus* and other more highly specialized sabre-tooths, I do not think that its presence necessarily indicates that this form is to be included in the genus *Hoplophoneus.* In a *Deinictis* specimen (No. 10257) from the White River beds I find similar, though somewhat weaker, notches separating incipient protostyles on P^4 and P^3 of both right and left series.

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M^1 is small and is narrow transversely. As in *Nimravus* and *Hoplophoneus*, it is without an inner protocone lobe. There are apparently three closely connate roots, the inner and antero-external being closely united, and the postero-external much reduced.

Systematic Position.—This species differs from all of those previously described from the John Day fauna. Like *Pogonodon platycopis* described by Cope from the John Day, it resembles *Hoplophoneus* in the large size of the canines, and in the reduced P^2 and P^3. It further resembles *Hoplophoneus* in the absence of a deuterocone on P^4, in the tendency to develop a protostyle on this tooth, and in the reduction of the inner lobe of M^1. Excepting the less marked lateral compression of the superior canine, the principal characters of the dentition as known are apparently closer to *Hoplophoneus* than to *Deinictis*. Affinities with *Deinictis* are more apparent in the skull characters. The root of the zygomatic process of the squamosal is not produced inferiorly, and the posttympanic process is not extended inferiorly to such an extent as in *Hoplophoneus* and other highly specialized sabre-tooths with long superior canines. The form of the frontals, nasals, fronto-maxillary suture, paroccipital process, posttympanic process and of the root of the zygomatic process of the squamosal all approach the characters seen in *Deinictis*. The very large size of the temporal fossae indicates large temporal muscles, and probably a heavy lower jaw with a large coronoid process as in the *Deinictis* forms.

This species must be considered a very advanced form of the deinictid group, and finds its closest affinities with the two John Day species *platycopis* and *brachyops*, which have been separated from *Deinictis* as a distinct genus, *Pogonodon*, by Cope. It differs from *P. platycopis* considerably in size, in the form and proportions of the posterior portion of the cranial region, and in the form of the narrow M^1. With considerably smaller skull measurements in *P. davisi*, the occiput and sagittal crest are absolutely much higher. As the skull is absolutely much smaller, this difference in the cranial region is evidently not due to sex. The relation of the superior outline of the fronto-facial region and sagittal crest to each other seem also different from the arrange-

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ment in *platycopis,* but judgment on this character should probably be suspended, as the frontal region of the type of *platycopis* is imperfect. As far as I am aware, the character of the inner tubercle of the upper sectorial in *platycopis* is unknown. M^1 in *platycopis* is stated by Cope to be characterized by its great transverse extent, while it is exceptionally narrow in *davisi* and *brachyops.*

From *Pogonodon brachyops* it is distinguished by its relatively much larger canine, smaller P^3, narrower M^1, less abbreviated muzzle, and higher sagittal crest.

The species of the deinictid group in the John Day beds include two types. One is represented by *Deinictis cyclops,* which corresponds quite closely in nearly all of its characters to the typical *Deinictis* of the White River. The other group is represented by *davisi, brachyops* and *platycopis.* The second group seems to belong pretty definitely with the deinictids, but represents such a degree of advance away from the typical *Deinictis* that it becomes important to refer to it as a distinct division. These species are characterized particularly by increase in the size of the canines, though not to a great extent in the vertical length, reduction of the anterior premolars, loss of M_2 and of the metaconid of M_1, and reduction of the inner lobe of M^1 in two species. In the only species in which the inner side of the superior carnassial has been examined, the deuterocone is reduced. In all three of the species the frontal region seems to be wide, the temporal fossae are exceptionally large, and the auditory meatus is appreciably narrowed by the posttympanic process. The species thus grouped seem to resemble each other more closely than they do other forms, and stand in decided contrast in most characters to *Deinictis cyclops* of the same beds.

In order to express in the classification the relation of these John Day species to each other and to the typical deinictids of the Oligocene, it seems to me advisable to use the arrangement proposed by Cope, and to separate *platycopis, brachyops,* and *davisi* as the *Pogonodon* group, of at least subgeneric rank.

Of the extremities of the Pogonodons very little is known, but Cope has shown that the limbs were slender and the feet narrowed as in the running types seen in *Nimravus* and *Deinictis.*

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MEASUREMENTS.

	mm.
Length of skull, anterior side of upper canine to posterior side of occipital condyles	197
Length from postorbital process to inion	117
Width across zygomatic arches	157
Width across postorbital processes	84.5
Least diameter above orbits	55.5
Height of inion above foramen magnum	55
Width of occiput at middle	36.5
Height of sagittal crest above parietal foramen	39
Width of palate between upper canines	30
Width of palate between deuterocones of sectorials	50
Length, posterior side C to posterior side M^1	58.5
Length, anterior side P^3 to posterior side M^1	39
Superior canine, antero-posterior diameter of alveolus	23
Superior canine, transverse diameter of alveolus	12
I^2, transverse diameter of alveolus	*a*5
I^3, transverse diameter of alveolus	*a*8.2
P^2, antero-posterior diameter of alveolus	4
P^3, antero-posterior diameter	14.5
P^4, antero-posterior diameter	23
P_4, transverse diameter across deuterocone	11.75
M^1, antero-posterior diameter	6
M^1, transverse diameter	6.5

AGE AND STAGE OF EVOLUTION OF THE JOHN DAY CARNIVORE FAUNA.

Canidae.—Compared with the canids of other Tertiary faunas in America, the John Day dogs represent a stage of evolution which does not correspond closely to that of any other formation. The time relations of the genera are shown in the following table:—

	White River	John Day	Mascall and Deep River	Loup Fork
Daphaenus	x	.....	.....	.....
Paradaphaenus	.....	x	.....	.....
Cynodictis	x	x(?)	.....	.....
Nothocyon	.....	x	.....	....
Protemocyon	x	.....	.....	.....
Mesocyon	.....	x	.....	.....
Cynodesmus	.....	.....	x	.....
Temnocyon	.....	x	.....	.....
Tephrocyon	.....	.....	x	.....
Aelurodon	.....	.....	.....	x
Canis	.....	.....	x(?)	x(?)
Enhydrocyon	.....	x	.....	....

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Philotrox		x		
Hyaenocyon		x		
Oligobunis		x		
Proamphicyon	x			
Amphicyon				x
Dinocyon				x
Ischyrocyon				x
Cynarctus				x

Of the nine generic types of canids in the John Day fauna, only one, *Cynodictis,* is considered identical with a White River genus. The John Day form of *Cynodictis* has generally passed under the same specific name as that of the White River beds, but is distinguished from the latter by several characters. The brain case is larger and the teeth are in some respects more specialized. As a whole the type is more advanced than the White River species.

The genus *Paradaphaenus,* while not distantly removed from *Daphaenus* of the White River in some characters, is in many ways more advanced. The inner lobes of the upper molars are broad, with well-developed hypocone. Intermediate tubercles are also present on the crushing face. The brain case is relatively much larger in the John Day form.

The other John Day representatives of the Caninae are all generically quite distinct from any forms found in the White River. As suggested by several writers, many of the John Day genera represent advances along lines of specialization laid down in the White River epoch. In *Temnocyon,* the cutting function of the lower molars is a little more strongly expressed than the decided tendency in this direction already shown in one form of the White River *Daphaenus. Mesocyon* represents an advance over the *Daphaenus* type in the better development of the shear of the lower sectorial, and the partial reduction of the inner tubercle of the heel.

The three species referred to *Nothocyon* are closely related if not generically identical with the John Day *Cynodictis* (?). There can be hardly any question that the Nothocyons are a modification of this stock in which the upper carnassials have been shortened, the molars have approximated the quadrate crushing type, and the brain case has become extraordinarily

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large. This group is considerably advanced beyond the stage of development of the nearest forms in the White River.

The four remaining canid genera are generally referred to the simocyonine division of the Canidae, having its typical representative in the European *Simocyon.* They are all, as far as known, short-headed forms with heavy jaws and a more or less reduced dentition. While a reasonable doubt exists as to whether these genera are really closely related to the Simocyonines, they are all of a more specialized stage of development than the White River dogs. In some cases there seems to be good reason for believing that they are the more highly specialized descendants of White River forms.

The Loup Fork Canidae are characterized by the presence of the peculiar *Aelurodon* group; by several more or less bear-like genera of the amphicyonine type, *viz.: Amphicyon, Dinocyon, Ischyrocyon,* and *Cynarctus;* and by a few imperfectly known species closely resembling *Canis.* These groups all differ from the John Day dogs and, excepting possibly the case of *Canis,* there is apparently little direct connection to be traced. Even *Canis* is not to be definitely connected with any of the John Day genera. *Mesocyon* may not be far from its ancestral line, but stands rather as the representative of a type than as the ancestor itself.

One of the earliest forms which seems to lead toward the somewhat specialized Aelurodons is *Tephrocyon* of the Mascall. *Tephrocyon* may possibly be derived from a Mesocyon-like type of the John Day. The amphicyonine canids of Loup Fork represent a branch of the family not known in the John Day and White River. A satisfactory statement of the relative stages of evolution reached in these divisions is difficult, as they are so different, but the degree of advance exhibited by the Loup Fork fauna is on the whole greater. In the *Canis* type an additional factor is introduced, as the Loup Fork species referred to *Canis* appear to be closer to a recent genus than to any John Day form.

In comparison with the Deep River beds, generally considered as older than the Loup Fork and near the age of the upper portion of the John Day, there is but little material from which to draw conclusions. The genus *Cynodesmus* is near *Mesocyon*

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in most of its characters. The Deep River species referred to *Canis* point toward a later period than John Day.

Fortunately the position of the Tertiary deposits of Eastern Oregon is not dependent on the relationships of the John Day fauna alone. The stratigraphic relations of the Mascall beds to the John Day are well known, and in the Mascall valuable canid remains have been obtained. The physical history of the region shows the Mascall to be separated from the John Day by at least one period of erosion and by the epoch of the accumulation of the Columbia Lava. The best known canid from these beds, *Tephrocyon*, is in many respects similar to *Canis*, but differs in other characters, and is in general a more primitive form than *Canis*. In still other characters it points toward the *Aelurodon* group. It may be near the ancestors of *Aelurodon*, and therefore probably older than the Loup Fork. The relationships of the Mascall Canidae, and the stratigraphic relations taken together indicate that the epoch of the Mascall beds is not far from that of the Deep River. The position of the John Day below these beds puts it into a division much earlier than the Loup Fork.

Felidae.—Remains of representatives of the Felidae are known in Eastern Oregon only from the John Day beds. The relation of these forms to those of the White River and Loup Fork are shown in the following table. The number of species is indicated for each genus.

	White River	John Day	Loup Fork
Deinictis	4	1	.....
Pogonodon	.....	3	.....
Nimravus and *Archaelurus*	.....	3	.....
Hoplophoneus	6	2	.....
Eusmilus	1	.....	.....
Machaerodus	.....	.....	1(?)
Pseudaelurus	.....	.....	1
Felis	.....	.....	2(?)

Compared with the White River cats, the Felidae of the John Day have sometimes been considered the more primitive, having fewer specialized forms of the *Hoplophoneus* type, no *Eusmilus*, almost as many of the deinictids, and the larger part of the whole representation of the family made up of the apparently very primitive forms of the *Nimravus-Archaelurus* group.

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In the two genera, common to the John Day and White River, the John Day species are relatively specialized forms. *Hoplophoneus cerebralis,* and the doubtful *H. strigidens* of the John Day are not less specialized than the White River forms, and in some characters show an advance. Of the *Deinictis* group the single typical species, *D. cyclops,* has more slender superior canines than the White River species, and the mandible is relatively slender. The upper sectorial is characterized by the large size and prominence of the deuterocone. The brain case is said by Cope to be rather large.

The three deinictids separated as *Pogonodon* show advance beyond the White River *Deinictis* in their larger size, heavier canines; reduced M^1; loss of M_2, of metaconid of M_1, and of deuterocone of P^4; reduced premolars; and probably in foot structure also, although this is as yet very imperfectly known.

The remaining forms, which are included in the *Nimravus-Archaelurus* group, have appeared to represent more primitive types than any of the White River felines, and being the dominant type of the John Day fauna, their presence has naturally tended somewhat to unsettle conclusions as to the stage of evolution and age of these beds which have been drawn from other evidence. As has been shown under the discussion of *Archaelurus* and *Nimravus,* the forms of this group, while possessing a somewhat primitive dentition, show in it some marks of advance not seen in the nearest White River forms. Moreover, we do not find associated with this apparently primitive dentition the primitive type of extremity which should accompany it if this were an especially low or early stage in the evolution of the group. The limbs are relatively long and slender and indicate development of speed rather than prehension, as in the hunting leopard. We should therefore expect to find that in *Archaelurus,* as in the living hunting leopard (*Cynaelurus*), specialization of the feet for running, with weaker prehension, would be correlated with short canines; and that the cheek teeth, having more work to perform in holding and killing prey, would be less reduced, and would be more efficient weapons.

Compared with the genus *Deinictis,* which also possessed rather slender limbs with an apparently primitive dentition,

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Archaelurus shows greater reduction of the lateral digits in the posterior limb, and a relatively longer metapodial region. In dentition and skull *Archaelurus* is more primitive than *Deinictis* in the frequent possession of a very small P^1, in the lack of inferior projection of the posttympanic process and of the root of the zygomatic process of the temporal, and in the absence of a flange on the lower jaw. The latter character is associated apparently with less pronounced elongation and lateral compression of the upper canines. *Archaelurus* is, however, more specialized than the typical *Deinictis* in lacking a metaconid on M_1; in the reduction of the deuterocone of P^4, and of the inner lobe and root of M^1; and in the possession of the peculiar exostoses on the mandibular rami. On the whole, it does not appear that the dentition in the *Nimravus-Archaelurus* group is less specialized than that in *Deinictis*. In the loss of the inner tubercles on both upper and lower carnassials and on the upper molar it certainly shows a distinctly advanced type.

Though *Archaelurus* has been considered by many as the type ancestral to *Deinictis*, there seems to be no good reason for supposing such a relationship to have existed, particularly as the evidence indicates that *Archaelurus* flourished in association with the most advanced members of the deinictid group. While in some of the characters which distinguish the true sabre-tooths *Archaelurus* is nearer the primitive cats than *Deinictis*, the same may be said of *Felis*. Just as in *Felis*, though to a less extent, the line of development of *Archaelurus* may have taken a different direction from that in the true sabre-tooths and the emphasis have been put on other features.

The apparent near kinship of the *Nimravus-Archaelurus* forms with *Ailurictis* occurring in the lower Oligocene of Europe is sometimes advanced as strong evidence of antiquity of the John Day fauna. Our present knowledge of this group seems to indicate an Old World origin of these American John Day genera, but the American species are somewhat more advanced in reduction of the lateral digits, and possibly in the reduction of the deuterocone of P^4. The exostosis of the mandible may also indicate a more specialized stage. If *A. sivalensis*, of the Indian Siwaliks, is a member of this group, the genus must have been strongly

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persistent, and its occurrence in the John Day would not necessarily indicate Oligocene age.

In the Loup Fork, the species of true *Felis* and of *Machaerodus* represent a more advanced stage of development and a closer approximation to the recent fauna than is found in either the John Day or White River.

Conclusions.—Taken together, the Canidae and Felidae of the John Day represent a stage of evolution somewhat more advanced than that reached in the White River and less advanced than that of the Loup Fork. Compared with the known faunas of Europe, they appear to be not older than the middle Oligocene of Fontainbleau and not as young as the middle Miocene of Sansan.

Issued November 30, 1906.

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EXPLANATION OF PLATE I.

Tephyrocyon rurestris Condon.

From the Mascall beds at Cottonwood, John Day Valley, Oregon.

All figures three-fourths natural size.

Fig. 1. Left side of cranium with atlas. Page 6.

Fig. 2. Superior aspect of left inferior dental series.

Fig. 3. Inferior aspect of right superior dental series.

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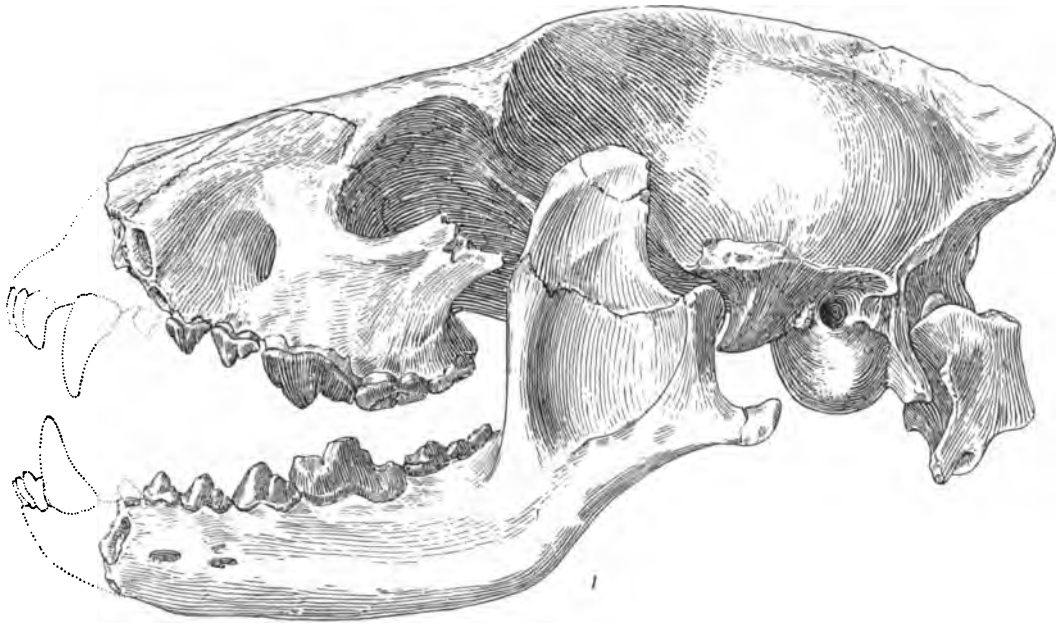

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EXPLANATION OF PLATE 2.

Fig. 1. *Nothocyon geismarianus mollis*, n. var. No. 90. Middle John Day, Turtle Cove, John Day Valley, Oregon. × ¾. Page 13.

Fig. 2. *Nothocyon lemur* Cope (?). No. 10208. John Day beds, Logan Butte, Crook County, Oregon. × ¾. Page 15.

Fig. 3. *Nothocyon lemur* Cope (?). Natural cast of the brain case from above. No. 10209. Middle John Day, Blue Basin, Turtle Cove, John Day Valley, Oregon. × ¾. Page 15.

Fig. 4. *Cynodictis* (?) *oregonensis*, n. sp. Outer side of left ramus of mandible. No. 316. Middle John Day, Blue Basin, Turtle Cove, John Day Valley, Oregon. × 1. Page 11.

Fig. 5. *Cynodictis* (?) *oregonensis*, n. sp. Superior aspect of right M_1. No. 365. Middle John Day, below Clarno's Ferry, John Day River, Oregon. × 2. Page 11.

Fig. 6. *Nothocyon latidens* Cope (?). Outer side of left M_1. No. 88. Middle John Day, Turtle Cove, John Day Valley, Oregon. × 2. Page 15.

Fig. 7. Superior aspect of specimen No. 88 shown in fig. 6. × 2.

Fig. 8. *Nothocyon lemur* Cope (?). Inferior aspect of left superior P^4, M^1, and M^2. No. 1104. Middle John Day, Rudio Creek, Grant County, Oregon. × 2. Page 14.

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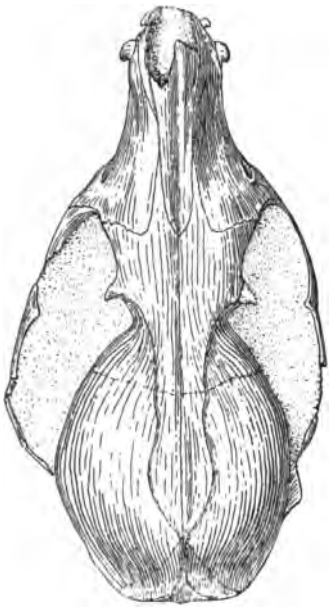

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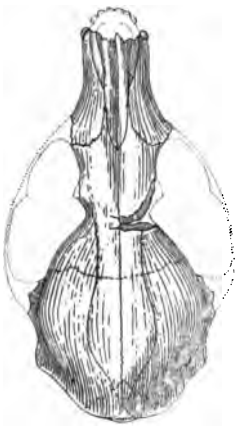

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EXPLANATION OF PLATE 3.

Fig. 1. *Nothocyon geismarianus mollis*, n. var. No. 90. Middle John Day, Turtle Cove, John Day Valley, Oregon. × .73. Page 13.

Fig. 2. *Temnocyon altigenis* Cope. No. 9999. Middle John Day (?), Logan Butte, Crook County, Oregon. × .71. Page 23.

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EXPLANATION OF PLATE 4.

Archaelurus debilis major, n. var. No. 1681. Middle John Day, Logan Butte, Crook County, Oregon. × .53. Page 43.

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EXPLANATION OF PLATE 5.

Archaelurus debilis major, n. var.

Figures three-fourths natural size.

Fig. 1. Left pes. No. 2256. Middle John Day, Logan Butte, Crook County, Oregon. Page 46.

Fig. 2. Right tibia. No 110. Middle John Day, Blue Basin, Turtle Cove, John Day Valley, Oregon. Page 47.

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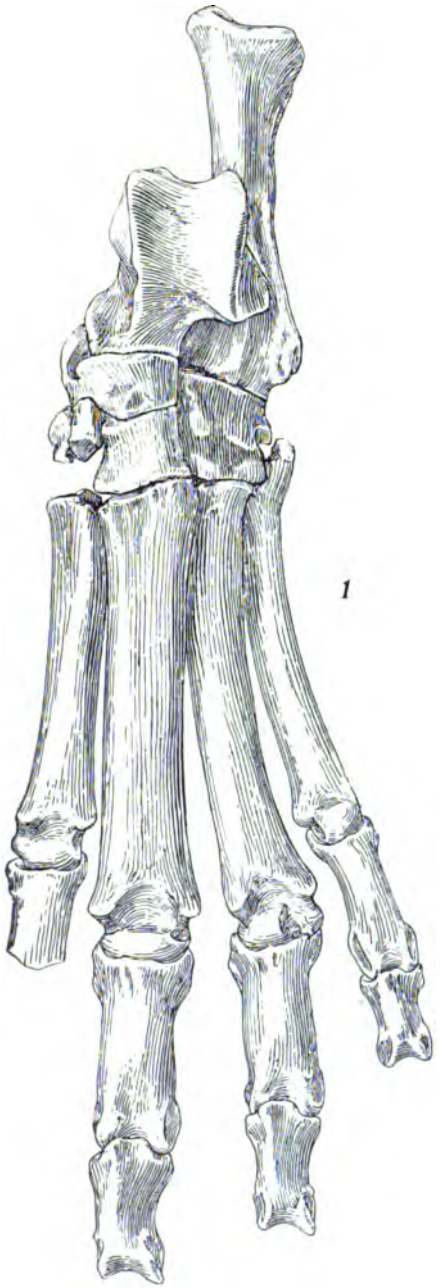

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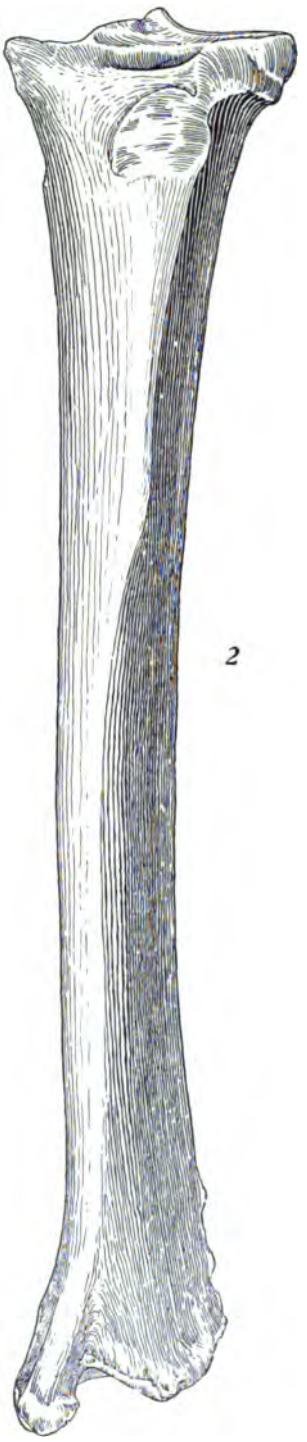

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EXPLANATION OF PLATE 6.

Pogonodon davisi, n. sp.

Upper John Day, five miles southeast of Monument, Grant County, Oregon.

Fig. 1. Side view of skull No. 789. × ½. Page 54.

Fig. 2. Inferior aspect of palatal region. No. 789 shown in fig. 1. × ½.

Fig. 3. Superior aspect of cranium shown in fig. 1. × ½.

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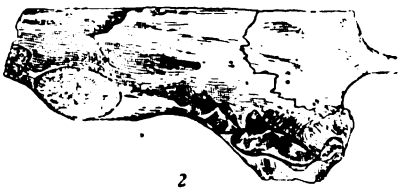

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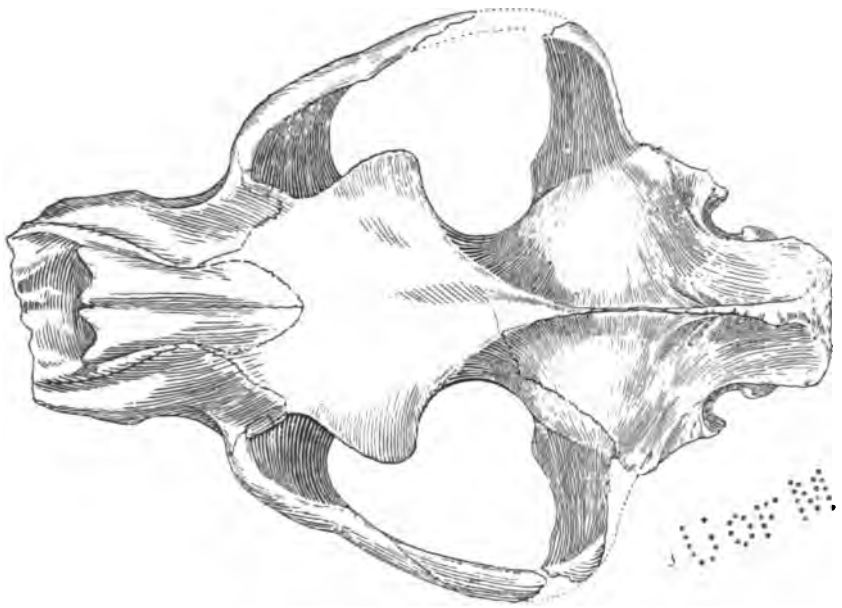

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UNIVERSITY OF CALIFORNIA PUBLICATIONS
BULLETIN OF THE DEPARTMENT OF
GEOLOGY
Vol. 5, No. 2, pp. 65-66 ANDREW C. LAWSON, Editor

SOME EDENTATE-LIKE REMAINS FROM THE MASCALL BEDS OF OREGON.

BY
WILLIAM J. SINCLAIR.

The writer has recently received from Professor J. C. Merriam for determination and description a large ungual phalanx collected in the Mascall beds of Oregon, by Mr. J. C. Sperry, while a member of the University of California expedition of 1900. The specimen (No. 1096, Univ. Cal. Palae. Col.), represented natural size in the accompanying figures (figs. 1 to 3), is from the

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Figs. 1 to 3. Claw of an Edentate (?) from the Mascall beds: fig. 1, from the side; fig. 2, from above; fig. 3, from below. All figures three-fourths natural size.

Mascall beds exposed on the north side of the main road between Rattlesnake Creek and Birch Creek, Wheeler County, Oregon.

Although somewhat fragmentary, this material is of peculiar interest, as it apparently pertains to a gravigrade edentate. The

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tip of the claw and the dorsal portion of the trochlear surface have been broken off. The claw is laterally flattened, with a faint indication of a shallow median cleft (fig. 2). Its base is sheathed in a bony hood, now considerably broken. The trochlear surface is divided by a high median ridge, as in the Gravigrada. Inferiorly there is a large subungual process for the extensor tendons, perforated by a pair of ungual foramina (fig. 3). The lateral surface of the claw is rugose, showing the impression of numerous vascular canals indicating the presence of a horny sheath.

Remains of supposed Edentates have been described from the John Day beds of Oregon (*Moropus distans, M. senex*), but these are more probably to be regarded as the American representatives of *Chalicotherium.*[1] The absence of a deep median cleft in the ungual phalanx and the presence of a bony hood are sufficient to separate the animal to which the material described in the present note pertained from any relationship with the Chalicotheres. On the other hand, the Mascall specimen agrees in every respect with the structure of the claws in the Megalonychidae. Should the above determination prove to be correct, the specimen just described will represent the earliest gravigrade remains known in North America.

[1] Communicated by Mr. O. A. Peterson.

Issued December 6, 1906.

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UNIVERSITY OF CALIFORNIA PUBLICATIONS
BULLETIN OF THE DEPARTMENT OF
GEOLOGY
Vol. 5, No. 3, pp. 67-70 ANDREW C. LAWSON, Editor

FOSSIL MOLLUSCA FROM THE JOHN DAY AND MASCALL BEDS OF OREGON.

BY
ROBERT E. C. STEARNS,
Honorary Associate in Zoology, United States National Museum.

Several years ago the writer examined a collection of shells obtained by parties from the University of California collecting in the John Day region, under the direction of Professor J. C. Merriam. A note on this material, with preliminary descriptions of new forms, was published in Science,[1] but without figures. It was intended at that time to republish the descriptions with figures at a later date. The following notes are in the main a reproduction of the articles from Science with the addition of figures of the new species.

[1] Science, N. S., Vol. 15, p. 153, 1902.

Professor Merriam's collection includes examples of the several species of land-shells heretofore described,[2] namely, *Epiphragmophora fidelis anticedens, Polygyra Dalli, Ammonitella Yatesi praecursor,* and *Pyramidula perspectiva simillima.* Of these four species there are numerous specimens and fragments. Dr. White's *Unio Condoni* was also obtained in considerable numbers. The foregoing represent all of the molluscan forms thus far reported from the John Day beds. Dr. White received his material from the late Professor E. D. Cope and Professor Thomas Condon, of the University of Oregon. Cope's specimens were obtained by Mr. Jacob L. Wortman, of the Army Medical Museum. These two collections included the same species.

Professor Merriam has made some interesting additions to the above brief list which are described below.

[2] C. A. White, Bull. U. S. Geol. Surv., No. 18, 1885; R. E. C. Stearns, Proc. Wash. Acad. Sc., Vol. 2, p. 651, 1900.

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HELIX (EPIPHRAGMORPHORA?) DUBOSIA nom. prov.

Figs. 3 and 4.

Type specimen No. 10001. Univ. Calif. Col. Invert. Palae., Middle John Day, John Day Valley, Oregon.

Shell orbicular, flattened, discoidal, periphery angulated or obtusely carinated; whorls six or more, deeply sutured and exhibiting strong growth striae. Apex whorls closely and slightly pitted. Aperture and umbilical region covered by a portion of the matrix in which the shell was imbedded.

Diameter (maximum), 24 mm., probably 26 to 26½ mm. when perfect. Elevation, about 10 mm. A sufficient portion of the shelly substance intact admits of the above description. Number of specimens, six; of these the individual described is the largest and most perfect. The smaller examples consist mainly of the upper whorls.

With more and better material it is quite probable that the foregoing might prove to be an angulated, dwarfed, depressed aspect of the living *fidelis,* or *mormonum;* it also suggests the form known as *Hillebrandi.* Nearly all of the material is in a very unsatisfactory condition, with no color indications to assist in determination. While for these reasons the conclusions may be regarded as more or less arbitrary, the general character and relationship is believed to be fairly well pointed out.

PYRAMIDULA LECONTEI, n. s.

Fig. 2.

Type specimen No. 10000. Univ. Calif. Col. Invert. Palae., John Day, Bridge Creek, Oregon.

Shell small, orbicularly depressed, widely and deeply umbilicated; whorls four and a half to five, rounded, closely and conspicuously ribbed except on the apex, which is nearly smooth; the ribbing extending into the umbilical cavity; the grooves between the ribs nearly as wide as the ribs are thick; the suture deep; aperture nearly circular or rounded lunate; edge of the lip simple. Diameter (maximum), 8½ mm. Elevation, nearly 5 mm. A single example; the last whorl has been broken back somewhat; the maximum diameter was probably 9 to 9½ mm. The specimen appears to be scarcely mature. The number, prominence, and

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regularity of the ribs make this a very pretty shell. The general facies suggests relationship with the extraordinary group of helicoid forms so widely distributed throughout the vast area denominated by Mr. W. G. Binney,[3] the "Central Province," and listed by Dr. Pilsbury in his recent catalogue as number 340[4] (*P. strigosa* and numerous races or varieties). A comparison of *P. Le*

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Fig. 1. *Limnaea maxima* nom. prov. Natural size.
Fig. 2. *Pyramidula Le Contei*, n. s. × 1½.
Figs. 3 and 4. *Helix* (*Epiphragmorphora?*) *dubiosa* nom. prov. Natural size.

Contei kindly made for me by Professor Dall, with the large series of the *strigosa* group in the National Museum, determines it, as he says, to be "different from anything we have in the collection."

In memory of the late Professor Joseph LeConte, I have attached his name to the above form.

[3] "Manual of American Land Shells," Bull. 18, U. S. National Museum.
[4] "Classified Catalogue of Land Shells of North America," etc. Philadelphia, April, 1898.

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LIMNAEA MAXIMA nom. prov.

Fig. 1.

Type specimen No. 10002. Univ. Calif. Col. Invert. Palae., Mascall beds, three-quarters of a mile east of Belshaw's ranch, John Day Valley.

Partially exposed in portions of a fine compressed sediment of lacustrine origin are several casts of a very large *Limnaea,* suggestive in a general way of the circumboreal *L. stagnalis,* but so much distorted as to preclude a more definite description. For convenience this may be known provisionally as *L. maxima.*

INDETERMINATE FORM.

In addition to the species herein described, the material submitted to me by Professor Merriam included a small globose form about the size of a small pea; there are several examples, so disguised by adherent particles of matrix as to make it doubtful whether they belong to terrestrial or aquatic groups, with a presumption in favor of the former.

Issued December 6, 1906.

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UNIVERSITY OF CALIFORNIA PUBLICATIONS
BULLETIN OF THE DEPARTMENT OF
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Vol. 5, No. 4, pp. 71-73, Pl. 7 ANDREW C. LAWSON, Editor

NEW CESTRACIONT TEETH FROM THE WEST-AMERICAN TRIASSIC.

BY

EDNA M. WEMPLE.

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INTRODUCTION.

In the summer of 1902 a palaeontological expedition from the University of California obtained a number of cestraciont teeth in the Middle Triassic beds exposed in the West Humboldt Range of Nevada. A second expedition in 1905 found additional material at other localities in the same beds. Teeth of these types are known to occur elsewhere at horizons from the Middle Triassic to the Upper Cretaceous, but as yet these specimens, with a few fragmentary teeth from Shasta County, California, appear to be the only cestracionts known in the Triassic of North America. All of the specimens obtained seem to represent new species, which are probably to be considered as characteristic fossils of this horizon of the Triassic.

ACRODUS ALEXANDRAE, n. sp.

Pl. 7, figs. 5 and 6.

Type specimen, one detached tooth, No. 9874, Univ. Calif. Col. Vert. Palae. From the upper part of the Middle Triassic, Fisher Cañon, West Humboldt Range, Nevada.

The tooth is large, elongated, and with a faint median keel. The crown is low and wider than the root. The overhanging margins are very deeply and sharply serrated. This ornamentation

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is coarser than in any other species of *Acrodus* known to the writer. Only one of the serrations is connected with the ridges higher up on the crown. The middle of the crown is much wider than the ends, which narrow gradually. The longitudinal crest on the crown is a very narrow but well defined ridge which continues unbroken along the entire surface of the crown. Immediately above the serrated lateral margin the crown is smooth. Half way up the side of the tooth a series of delicate ridges arises and runs into the longitudinal crest.

ACRODUS OREODONTUS, n. sp.

Pl. 7, figs. 1, 2.

Type specimen No. 10251, Univ. Calif. Col. Vert. Palae. From the upper part of the Middle Triassic, Cottonwood Cañon, West Humboldt Range, Nevada.

The teeth are elongated, depressed, with a median prominence, and a well defined median ridge. No lateral prominences are present. The coronal contour is strongly rounded. Coarse wrinkles converge toward the apex and the longitudinal crest. This convergence is more noticeable on one surface of the tooth. On this surface the distance from the base to the lower edge of the crown is about half the same distance on the other surface. This surface is more coarsely ornamented than the opposite side. The straight longitudinal crest is situated medially on the crown.

HYBODUS NEVADENSIS, n. sp.

Pl. 7, fig. 3.

Type specimen, one detached tooth, No. 10254, Univ. Calif. Col. Vert. Palae. From the upper part of Middle Triassic, Cottonwood Cañon, West Humboldt Range, Nevada.

Tooth cuspidate, crown relatively low and vertically striated, with one principal elevation situated a little away from the middle of the tooth. The lateral prominences are two in number. These prominences are well defined and sharply conical. No lateral denticles are present on the opposite side. The root is separated from the crown by a deep grove. The type specimen probably belonged to the symphyseal portion of the jaw, as it shows a high, robust, principal cone.

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HYBODUS SHASTENSIS, n. sp.

Pl.7, fig. 4.

Type No. 10255, Univ. Calif. Col. Vert. Palae. From the Upper Triassic at the west end of Bear Cove, Shasta County, California.

The crown supports a high, robust principal cone with a broad base. The upper portion of the principal cone is rather sharply narrowed. There are five lateral denticles, three on one side, and two faint elevations on the other; all are short and when preserved the tips are narrow. The sides of principal cone and all of the denticles are cut into numerous strongly marked ridges. The crown overhangs the base slightly. The base is wide, with one margin deeply scalloped.

Issued December 7, 1906.

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EXPLANATION OF PLATE 7.

Figs. 1 and 2. *Acrodus oreodontus*, n. sp. No. 10251. Middle Triassic, Cottonwood Cañon, West Humboldt Range, Nevada. × 1½.

Fig. 3. *Hybodus nevadensis*, n. sp. No. 10254. Middle Triassic, Cottonwood Cañon, West Humboldt Range, Nevada. × 2.

Fig. 4. *Hybodus shastensis*, n. sp. No. 10255. Upper Triassic, Bear Cove, Shasta County, California. × 2.

Figs. 5 and 6. *Acrodus alexandrae*, n. sp. No. 9874. Middle Triassic, Fisher Cañon, West Humboldt Range, Nevada. × 1.

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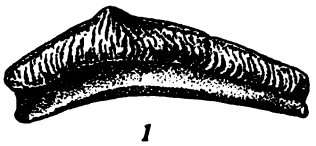

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UNIVERSITY OF CALIFORNIA PUBLICATIONS
BULLETIN OF THE DEPARTMENT OF
GEOLOGY
Vol. 5, No. 5, pp. 71-79, Pls. 8-9 ANDREW C. LAWSON, Editor

PRELIMINARY NOTE ON A NEW MARINE REPTILE FROM THE MIDDLE TRIASSIC OF NEVADA.

BY

JOHN C. MERRIAM.

In the summer of 1902 a joint expedition from Stanford University and the University of California visited the Middle Triassic outcrops of the West Humboldt range in Nevada to explore these beds for palaeontological material. Mr. V. C. Osmont, who represented the University of California, devoted himself to the search for vertebrate remains. He was fortunate in obtaining a number of reptilian specimens, which furnished the first satisfactory information concerning the nature of the marine saurians known to occur there.[1] The greater part of the material obtained by Mr. Osmont consisted of remains referable to ichthyosaurian forms.[2] Associated with the ichthyosaurs is a single specimen representing a form which does not closely resemble any described reptilian type. This specimen consists of several anterior cervical vertebrae, the greater part of a mandible with the dentition, and the inferior portion of the cranium. In collections obtained later from the same locality there are several fragmentary specimens showing similar structure. The peculiar features of this specimen separate it from other forms as a distinct genus and species, possessing the following characters.

[1] J. Leidy, Proc. Philad. Acad. Sc., Vol. 20, p. 177; and J. C. Merriam, Bull. Dept. Geol. Univ. Calif., Vol. 3, p. 107.

[2] A Primitive Ichthyosaurian Limb from the Middle Triassic of Nevada. J. C. Merriam, Bull. Dept. Geol. Univ. Calif., Vol. 4, p. 33.

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OMPHALOSAURUS NEVADANUS, n. gen. and sp.

Pls. 8 and 9, and Text-fig. 1.

Anterior vertebral centra biconcave. Rami of the mandible rapidly uniting anteriorly in a strong symphysis. Splenials broad and heavy. Dentaries united medially only a short distance in front of their posterior extremities, broad superior surface set with several rows of very low-crowned crushing teeth. Palatine region with broad edentulous pterygoid elements. Posterior portion of the palatines also apparently edentulous.

The vertebrae present are distinctly amphicoelous and the centra are nearly circular in vertical cross-section. They are in series at the back of the skull, and are evidently anterior cervicals.

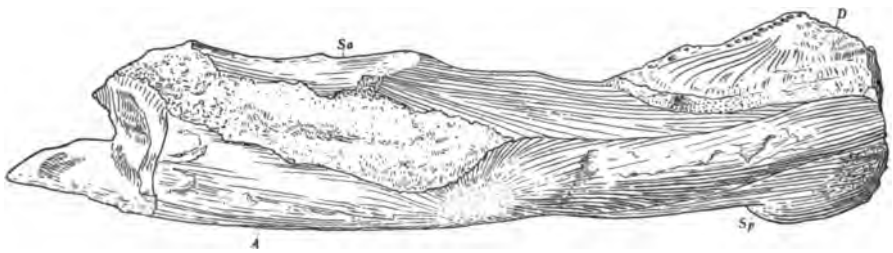

Fig. 1. *Omphalosaurus nevadanus,* n. gen. and sp.. Outer side of a portion of the right ramus of the mandible. *A,* angular; *Sa,* supra-angular; *D,* dentary; *Sp,* splenial. Middle Triassic, marine beds, South Fork of American Cañon, West Humboldt Range, Nevada. × ⅓.

The mandible has lost the articular region and is broken off a short distance in front of the symphysis. The angular, supra-angular, dentary and splenial are represented, with possibly some portions of other elements. The thickness of the jaw back of the symphysis is almost as great as the height. The rami unite in a very wide symphysis only a short distance in front of the posterior end of the dentaries. The angular extends unusually far forward between the splenial and the dentary. The heavy supra-angular shows no coronoid elevation; and no discrete coronoid element has been certainly recognized, though possibly present. As will appear from the discussion of the dentition, the development of a large coronoid elevation would almost have been expected to occur here, as in *Placodus.*

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The heavy splenials extend posteriorly only a short distance behind the dentaries before they begin to thin out rapidly. Anteriorly they are suddenly widened to meet in the symphysis. The transverse diameter of the splenials at the symphysis is more than twice their width behind this region. In front of the symphysis the splenials extend downward to form a part of the lateral face of the jaw.

The dentaries extend backward a short distance over the anterior ends of the supra-angulars, and are also in contact inferiorly with the anterior extension of the angular. Like the splenials, the dentaries are much expanded transversely in the symphysial region. The posterior ends extend backward as wing-like projections for a short distance behind the symphysis.

Situated on the dentaries are numerous small, button-like teeth, somewhat similar to those of some of the pycnodont fishes. The crowns are circular in cross-section, and the elevation is considerably less than the transverse diameter. There are at least three rows of teeth preserved on the right dentary, parallel with the median border. On the left dentary, teeth extend from the median line more than half of the distance to the outer margin, and appear to have been in numerous rows. The surface of the dentigerous area seems to have been convex.

A portion of the palatine region is fairly well exposed in the lower view of this specimen (pl. 9). The two large elements separated posteriorly, but uniting medially opposite the posterior ends of the splenials, are evidently pterygoids. Anterior to them on either side are apparently the palatines. Extending backward from a point a little in advance of the middle of the pterygoids is a median space which possibly represents the posterior nasal opening. On the superior side of the specimen (pl. 8) the structure is more indistinct. One of the palatine elements appears, *viz.:* a part of one of the pterygoids. In addition to this, two heavy bones (*a*) with lateral notches are situated just behind the symphysis. Posterior to these is a large expanded element (*b*), and a large emarginate bone (*c*). The flat posterior element may belong to the roof of the cranium. The laterally notched anterior bones might be vomers, or possibly premaxillaries. The large crescentic bone may pertain to the postorbital region.

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The groups of reptiles which this form most closely resembles in adaptation, so far as this is expressed in the structure of the parts present, are the Placodonts and the Rhynchosaurs. Both of these groups occur in the Trias, as does this form. The Placodonts were marine, and lived in approximately the same epoch as *Omphalosaurus;* the Rhynchosaurs were probably somewhat later in appearance, and were not typical aquatic animals. Both types differ from *Omphalosaurus* in the character of the mandibular dentition and in the structure of the skull, so far as known.

The jaw of *Placodus* possessed a large coronoid elevation. The coronoid of the Rhynchosaurs is not so well known, though such an element of considerable size seems to have been present in *Hyperodapedon minor.* The region of the coronoid is not well preserved in the *Omphalosaurus* specimen, and no definite statement as to the presence or absence of the bone can be made. In a form with crushing teeth like those seen here, such an elevation is to be expected, and it may be that the crescentic element (*c*) shown on plate 9 represents a discrete coronoid.

The structure of the mandible does not agree with that of either the Placodonts or the Rhynchosaurs. The character of the palate, so far as is known, is quite different from that in both groups. If the palatal elements are correctly interpreted, the dentition cannot be compared with that of either Placodonts or Rhynchosaurs, so far as occurrence of the teeth is concerned. The mandibular dentition is nearer to *Hyperodapedon* than to *Placodus.*

Superficially this form has the appearance of a short-headed Synapsidan. The head was evidently not greatly elongated and the cranial region presumably relatively long. The structure of the palate and of the mandible are not unlike that in the Plesiosaurs. On the other hand, certain of the characters point toward the rhynchocephalian type. The mandibular dentition is paralleled in the diaptosaurian groups, and if the two anterior elements (*a*) are vomers, they probably correspond to the large prevomers of the Diapsida.

It is quite certain that *Omphalosaurus* represents a type far enough removed from other known reptilia so that it must form a distinct family, the Omphalosauridae, but the true position of

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this group is not at present entirely clear. It will not improbably be found to represent an independent ordinal group among the synapsidan forms. It is hoped that the true position of this genus may be more clearly defined by the discovery of more complete specimens at the same horizon as that from which this material was obtained.

Issued December 7, 1906.

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EXPLANATION OF PLATE 8.

Omphalosaurus nevadanus, n. gen. and sp. Superior aspect of a portion of the mandible with several displaced head bones and two vertebrae. *A*, angular; *Sa*, supra-angular; *D*, dentary; *Pt*, pterygoid; *V*, vertebrae; *a*, *b*, and *c*, doubtful elements. Middle Triassic, South Fork of American Cañon, West Humboldt Range, Nevada. × ½.

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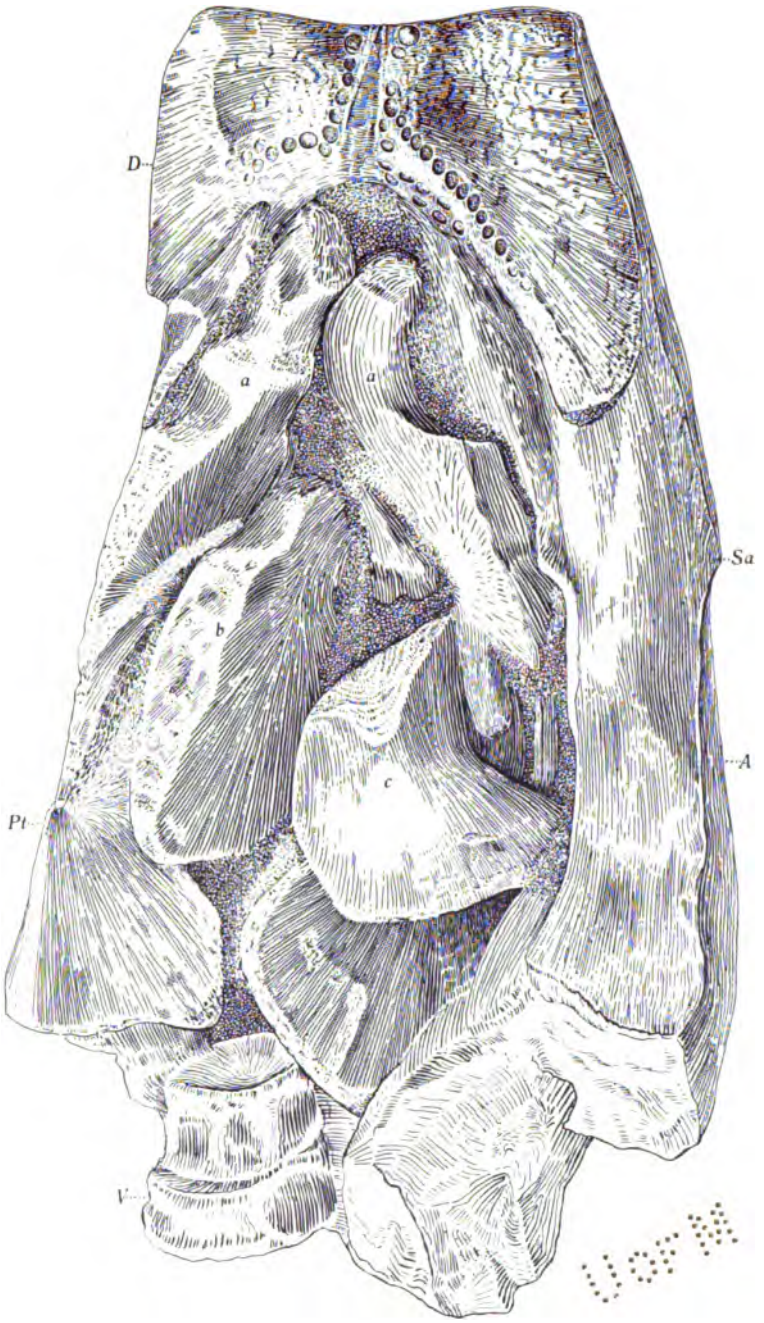

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EXPLANATION OF PLATE 9.

Omphalosaurus nevadanus, n. gen. and sp. Inferior view of a portion of the mandible with two vertebrae and several elements from the palatal region. *A*, angular; *Sp*, splenial; *Pt*, pterygoid; *Pl*, palatine; *V*, vertebrae. Middle Triassic, South Fork of American Cañon, West Humboldt Range, Nevada. × ½.

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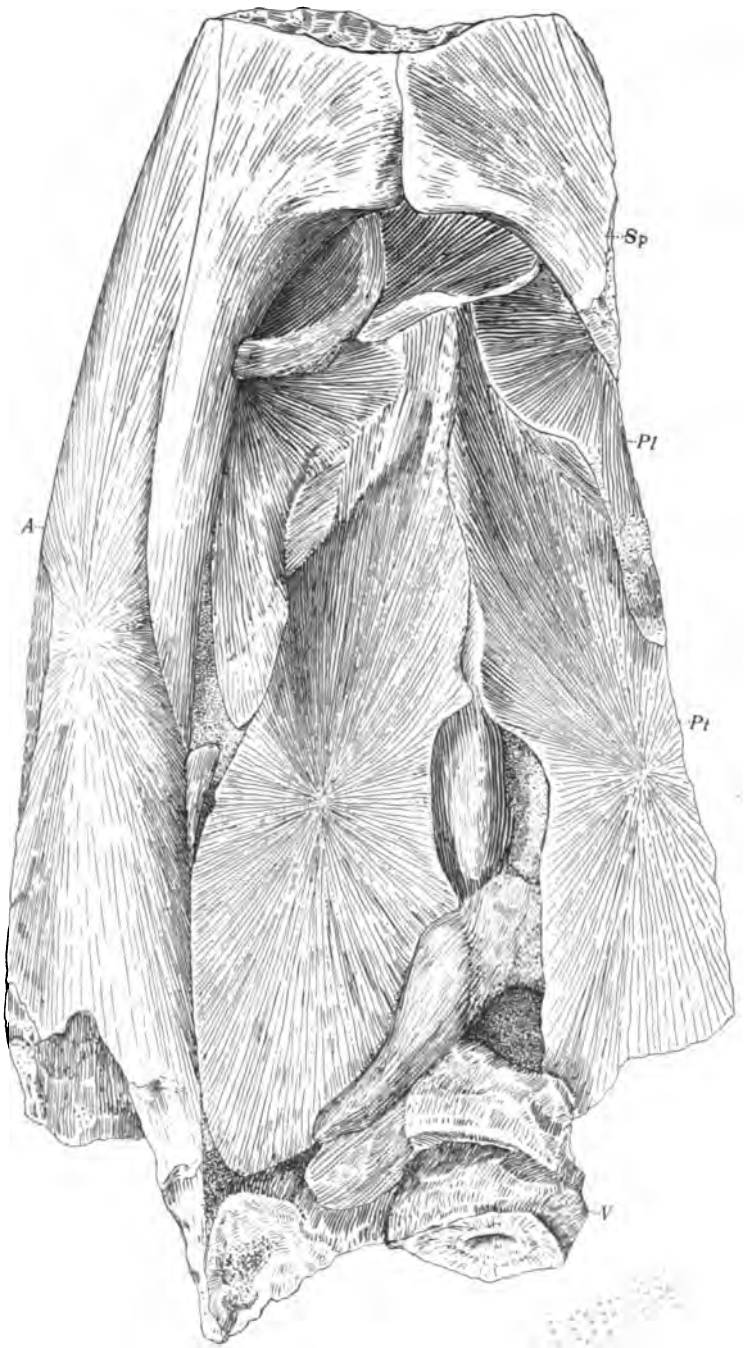

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UNIVERSITY OF CALIFORNIA PUBLICATIONS

BULLETIN OF THE DEPARTMENT OF

GEOLOGY

Vol. 5, No. 6, pp. 81-94, Pl. 10 ANDREW C. LAWSON, Editor

NOTES ON LAWSONITE, COLUMBITE, BERYL, BARITE, AND CALCITE.

BY

ARTHUR S. EAKLE.

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LAWSONITE.

Introduction.—New minerals are frequently discovered and the list of mineral names has largely increased since the appearance of Dana's System of Mineralogy in 1892. With very few exceptions, however, the minerals discovered since that date are to be classed as rare because they seldom occur abundantly and are usually confined to a single locality.

The discovery of a new mineral which is essentially a rock constituent is still rarer. While the introduction of new rock names is very prevalent, it is well known that such names are not generally based upon the presence of new constituents, but upon the presence and relative proportions of the old long known rock-forming minerals.

In the case of lawsonite we have a mineral of recent discovery of fairly wide distribution as a rock-forming mineral, and it is a matter of some surprise that it so long escaped the observation of petrographers.

Lawsonite was discovered in 1894 by Ransome and Palache[1] at Reed's Station, Marin County, California, as a deposit of large well developed crystals, and as a constituent of the glaucophane schists in that locality. This occurrence of large crystals is the only one so far known, but as a rock constituent it is interesting to note that almost coincident with its discovery by Ransome, the mineral was observed by Franchi[2] in the glaucophane rocks of the Piedmont district, Italy, and by Lacroix[3] in the saussuritic gabbros from Corsica, both writers noticing its presence as an unidentified constituent of their rocks.

Franchi observed the mineral as an unknown constituent associated with albite and muscovite, resulting from the alteration of the feldspars of an altered ophitic diabase found in the Maira Valley of the Piedmont Alps. He later mentions the same unknown minerals as having been found by Stella in little veins in a soda amphibolite, from the high valley of Chiana.[4] This uniden-

[1] Bull. Dept. Geol. Univ. Calif., 1895, 1, 301-312. Zeits. für Kryst., 1896, 25, 351-357.
[2] Bollet. del R. comit. geol., 1895, 2, 90.
[3] Miner. de la France, 1895, 1, 708.
[4] Bollet. della Soc. geol. Italiana, 1896, 2.

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tified constituent he subsequently identifies as lawsonite and adds that it occurs frequently in the glaucophane rocks of several valleys in the Piedmont Alps.[5]

Lacroix observed lawsonite in the rocks of Corsica and of New Caledonia.[6] The Corsican rock from the region about Bastia contains large crystals of diallage partly changed to glaucophane and actinolite, and surrounded by a greenish white mass which resolved itself into a mixture of lawsonite, albite, anorthite, chlorite, actinolite, and epidote. In New Caledonia the gabbros from the Diahot Valley consist of large unaltered crystals of diallage surrounded by a schistose mass of glaucophane needles and many distinct crystals and grains of lawsonite.

Viola[7] mentions lawsonite as a constituent of the gabbro-diabase-peridotite near the border between the compartments Basilicata and Calabrie, in southern Italy. The labradorite and bytownite feldspars of the diabases and gabbros have become sausuritized into a mixture of albite, mica, quartz, epidote, and lawsonite. He notes that when lawsonite is abundant epidote is scarce, and conversely, thus calling attention to the similar rôle of the two as metamorphic products.

Occurrences in California.—Lawsonite as yet has not been observed in this country outside of California. The type locality described by Ransome is a region of actinolitic and glaucophanitic schists. Much garnet occurs in the actinolitic schists, and occasionally schistose and compact masses of chlorite are found, presumably as an alteration of the actinolite-garnet rock.

Lawsonite does not occur as a regularly disseminated constituent of the regional schists, but is found sporadic, usually in large amounts mixed with actinolite and glaucophane or with chlorite, often forming boulder-like masses. The crystals described by Ransome occur in such a mass, consisting mainly of actinolite and muscovite with smaller amounts of glaucophane, epidote or zoisite, chlorite, and titanite. Some of the largest crystals are imbedded in a greenish-gray mass of flaky muscovite which forms a vein in the actinolitic mass. This micaceous min-

[5] Bull. Soc. Fr. Min., 1897, **20**, 5-7.
[6] Ibid., 309-312.
[7] Zeits. für Kryst., 1897, **28**, 553-555.

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eral was erroneously determined as margarite by Ransome, but a chemical analysis proves it to be muscovite. The analysis was kindly made for the writer by E. S. Larsen, Jr.,

SiO^2	48.42
Al^2O^3	28.41
FeO	2.10
CaO	0.48
MgO	3.81
Na^2O	1.95
K^2O	10.36
H^2O	4.72
	100.25

The size of the optic angle varies. Most of the plates have a large angle just within the field of the microscope, like ordinary muscovite, while other plates show a considerably smaller angle, perhaps between 50°–60°. It is quite possible that some of the plates have a higher percentage of silica than others, which may account for the smaller angle.

The presence of muscovite instead of margarite is more in accord with the observations of the other petrographers previously mentioned who report muscovite as an associate, and also with its occurrence elsewhere in the State. Epidote is quite subordinate in this mass; consequently almost the whole of the lime of the original rock has gone to the formation of lawsonite. The large amount of muscovite indicates that the original rock contained much potash feldspar, and in fact indications point to the probability that the boulders rich in lawsonite are remnants of a rock which was mineralogically different from the surrounding soda-rich rocks.

On the western slope of the Berkeley hills, north of Berkeley, there are several outcrops of actinolitic, glaucophanitic, and chloritic schists; and it was from this region that the new amphibole crossite, described by Palache,[8] was found. About three miles north of the town a chloritic boulder was found, resting upon an outcrop of chloritic schist which was very thickly charged with thin plates of lawsonite. The boulder presents a very striking appearance, due to the thin edges of the lawsonite standing out as bleached white ridges on the weathered surface

[8] Bull. Dept. Geol. Univ. Calif., 1894, 1, 181-192.

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of the dark green chloritic mass. The identity of these plates with lawsonite was not at first suspected, because of their distinctly different habit and association from the Marin County crystals, and their lack of the characteristic bluish tinge. The plates are basal, seldom more than 2–3 mm. thick, but often a centimeter or more in surface dimensions. Many of them are slightly thicker in the center and taper off towards the edges, giving a characteristic lenticular appearance to the broken edges. These basal planes are the only crystal faces present, the edges being broken and irregular in outline. The plates are apparently colorless when pure, but owing to inclusions and impregnations of chlorite they have mostly a greenish cast. An analysis sufficient for identification was made of the mineral, but the plates were too much impregnated with chlorite to warrant a complete analysis.

Analyses.—1. Analysis by the writer.

2. Analysis by Ransome and Palache.

3. Analysis by Hillebrand and Schaller.[9]

	1	2	3
SiO^2	38.43	37.71	38.45
TiO^2	——	——	0.36
Al^2O^3	33.39	32.43	31.35
Fe^2O^3			0.86
FeO	——	——	0.10
MnO	——	——	trace
CaO	16.85	18.15	17.52
MgO	——	——	0.17
K^2O	——	——	0.23
Na^2O	——	——	0.06
H^2O ignition	9.83	11.31	11.21
	98.50	99.60	100.33

Macroscopically the rock appears to be a very compact mass of scaly chlorite through which the lawsonite plates are thickly disseminated, but under the microscope, in addition to the chlorite and lawsonite, considerable muscovite and also dull brownish irregular grains of titanite or leucoxene are revealed.

The lawsonite sections are mostly rectangular or lenticular slabs, and their high relief easily distinguishes them from the

[9] Amer. Journ. Sci., 1904 (4), 17, 195-197.

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colorless muscovite. Basal sections of the mineral show fine cleavage lines parallel to the prism faces, the lines being very numerous and much resembling twinning striations, but no real twinning was observed. This highly developed cleavage parallel to the prism is brought out prominently in thin sections, and as a matter of fact the prismatic cleavage of lawsonite is not an easy cleavage because the plates break usually quite independent of the cleavage. The average hardness of these plates seems to be about 6, instead of the extreme hardness of 8.

The chloritic outcrop upon which the boulder rests shows no lawsonite, and is different in structure and composition from the boulder. It is an isolated boulder, and may have been transported and curiously found lodgment here, although there is the possibility that it is a lawsonitic phase of this particular outcrop. Chloritic masses are common about the bay which have been derived from the alteration of the actinolite-garnet schists, and the origin of this lawsonite-chlorite mass may have been due to the alteration of such a rock containing lawsonite, and in the change the lawsonite may have become recrystallized into the platy form.

A similar mass of chlorite occurs near San Luis Obispo. Specimens were collected by Dr. Fairbanks and given to the writer to determine the numerous thin glassy plates they contained. The rock is identical with the one above described, being essentially composed of chlorite, muscovite, and lawsonite. The plates are thinner and much more impregnated with chlorite than in the Berkeley rock.

In a paper read before the Cordilleran section of the Geological Society of America, W. O. Clark of Stanford University mentioned the occurrence of lawsonite in several localities in California, and in particular described a lawsonite-gneiss from Redwood. The rock consisted of quartz, glaucophane, and lawsonite, with some titanite or leucoxene, and the original rock was presumably a quartz diorite which occurs in the vicinity. P. Thelen[10] also mentions lawsonite as a constituent of some of the glaucophane schists of North Berkeley, lawsonite forming from 5–30 per cent. of the rock.

[10] Bull. Dept. Geol. Univ. Calif., 1905, 4, 221.

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A cursory examination of some of the crystalline schists of California, collected by G. D. Louderback, shows the presence of the same tabular crystals of lawsonite in specimens from different localities. Professor Louderback, who is making a detailed petrographical study of these rocks, states that thin sections of many of his specimens contain lawsonite which is not macroscopically visible.

Conclusion.—All of these observations prove conclusively that lawsonite has an extended distribution in the State of California. The mineral is generally considered as rare, but petrographically it cannot be so held, and in regions of dynamic metamorphism, whether glaucophane is formed or not, it may be expected. Comparatively little attention has been directed to it as a rock constituent, and this perhaps accounts for its omission from the list of metamorphic minerals by Van Hise in his excellent "Treatise on Metamorphism."[11] Rosenbusch in his new edition of the "Mikroscopische Physiographie," and Weinschenk in his "Gesteinbildene Mineralien" accord it proper recognition as a rock constituent.

The natural habitat of lawsonite seems to be in regions of glaucophanitic rocks, although glaucophane is not always directly associated with it. The opinion prevails that it is a product of the metamorphism of the soda lime feldspars of the basic rocks, the soda entering into the formation of glaucophane while the lime goes to lawsonite, which is analogous to anorthite with two molecules of water. Its similarity in formation to zoisite and epidote leads to the belief that it may occur in rocks outside of glaucophanitic provinces.

COLUMBITE.

Introduction.—San Diego County has become widely known through its deposit of rubellite-tourmaline in lepidotite at Mesa Grande, specimens of which have been sent to all parts of the world and are recognized as distinctly characteristic of this locality. More recently mines have been opened at Pala which produce rose and green tourmalines which equal any found in Maine, Siberia, or Brazil. The newest find of a gem mineral is the beau-

[11] Monograph XLVII, 1904, U. S. Geol. Survey.

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tiful lilac spodumene, kunzite. Beryl, topaz, and garnet of gem quality are also mined in the county, but these possess less value than the tourmaline and kunzite.

A crystal of columbite and several of beryl from San Diego County were loaned to the writer by Mr. Lazard Cahn, and a brief description is given here.

Occurrence.—The crystal of columbite came from the Little Three mine, near Ramona. It is short prismatic, measuring about 2 centimeters in length and width and is partly broken, so that some of the faces have been destroyed. Notwithstanding its broken condition, there are thirty-six faces present, representing thirteen forms, one of which is new.

Forms.—The observed forms are:

a {100}	*z* {150}	*s* {221}
b {010}	*y* {160}	*n* {211}
m {110}	*e* {021}	*β* {121}
g {130}	*u* {111}	*o* {131}
		r {141} new

Measurements.—The crystal was measured with the two-circle goniometer, and the average values for ϕ and ρ for the thirteen forms are shown in the following table:

No.	Letter	Symbol		Measured				Calculated			
		Gdt.	Miller	ϕ		ρ		ϕ		ρ	
1	*b*	0∝	010	0°	00′	90°	00′	0°	00′	90°	00′
2	*a*	∝0	100	89	45	90	00	90	00	90	00
3	*m*	∝	110	68	46	90	00	68	05	90	00
4	*g*	∝3	130	39	31	90	00	39	38	90	00
5	*z*	∝5	150	25	32	90	00	26	26	90	00
6	*y*	∝6	160	22	26	90	00	22	30	90	00
7	*h*	02	021	0	36	35	16	0	00	35	36
8	*r*	14	141	31	28	60	09	31	52	59	19
9	*o*	13	131	39	31	54	32	39	38	54	21
10	*β*	12	121	51	30	49	59	51	11	48	48
11	*u*	1	111	67	36	43	59	68	05	43	48
12	*s*	2	221	68	42	62	30	68	05	62	28
13	*n*	21	211	78	53	61	46	78	37	61	09

The faces of *n* and *s* were dull and the rest bright but somewhat vicinal or wavy, so that close readings could not be had.

The new form *r* (141) had narrow faces, but all four on the upper half of the crystal were present. Fig. 1, Pl. 10, shows the crystal as it appears.

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BERYL.

Occurrence.—Two distinct varieties of beryl are found in the county, one green and the other pink or rose in varying shades. The green crystals came from Rincon, and are characterized by a long slender prismatic habit, one end only having terminations as a rule.

Forms.—The forms occurring are:

$m\{10\bar{1}0\}$	$c\{0001\}$	$o\{11\bar{2}2\}$
$i\{21\bar{3}0\}$	$p\{10\bar{1}1\}$	$y\{13.1.1\bar{4}.1\}$?
$a\{11\bar{2}0\}$	$s\{11\bar{2}1\}$	

In the prismatic zone the unit prism usually predominates, yet the dihexagonal prism is sometimes equally large; the second order prism is very narrow when present, but is generally absent. The dominant terminal form is s $(11\bar{2}1)$, leaving the unit pyramid as small triangles. The base and o $(11\bar{2}2)$ are small planes. The indices of the form y $(13.1.\overline{14}.1)$ are doubtful because the faces were very dull and only approximate reading could be made.

	ϕ	ρ
Measured	3° 26′	83° 45′
Calculated	3° 40′	82° 41′

Two of the crystals are milky green and opaque and show the unit prism with i and a as mere line faces. The terminal forms are s, p, c and an indeterminate form between m and s, which was too dull for measurement.

The rose beryls came from the Little Three mine, near Rincon. They are short prismatic and doubly terminated.

The forms present are:

$m\{10\bar{1}0\}$, $s\{11\bar{2}1\}$, $p\{10\bar{1}1\}$, and $c\{0001\}$; in which c and s predominate.

TUBULAR CALCITE.

Occurrence.—During the exploration of the Potter Creek cave in Shasta County, California,[12] W. J. Sinclair collected some of the smaller stalactites which abound in the cave.

Description.—The ordinary stalactitic shapes as well as hollow cylinders are common, and their formation has been due to

[12] Univ. Cal. Publications, Amer. Arch. and Ethnology, 2, No. 1.

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continued crystallizations of rhombohedrons. The tubes are several inches long, and their round surfaces show the outlines of small rhombohedrons. They break always with the calcite cleavage. The stalactites have the customary shape and also show the outlines of crystals, and their points are always terminated by a clear crystal, consisting of steep rhombohedrons 4R and –2R with their edges modified by scalenohedrons. The faces of the scalenohedrons were too rounded for measurement.

The stalactites in the cave are continually wet, water filling their hollow centers and constantly dripping from them, so that the growth is by successive crystallization instead of by the common evaporation and deposition of the carbonate.

BARITE.

Occurrence.—Specimens of porous, yellowish brown earthy limonite containing minute crystals of barite were collected by F. M. Anderson from the Pine Hill mine, Nevada County. Attention has previously been called to this mine as containing gold associated with barite.[13]

The crystals are perfectly colorless and exhibit two habits. The crystals are slender prismatic, but in one habit they have pointed ends while in the other the base is the only termination.

Forms.—The forms present are:

a {100}	η {320}	*d* {102}
b {010}	π {530}	*o* {011}
m {110}	χ {130}	*z* {111}
λ {210}	*c* {001}	*f* {113}

The front pinacoid is vertically striated and broader than the prisms. The reflections from the unit prism and from the terminal faces were exceedingly sharp. Most of the crystals have pyramidal terminations and Fig 2 shows the general type.

Measurements.—The measurements were made with the two-circle goniometer, and the angles measured and calculated are as follows:

[13] Amer. Jour. Sci., 1892 (4), 44, 57; 1894 (4), 47, 467.

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No.	Letter	Symbol Gdt.	Symbol Miller	Measured ϕ	Measured ρ	Calculated ϕ	Calculated ρ
1	*c*	0	001	0 00	0 00	0 00	0 00
2	*b*	0∝	010	0 00	90 00	0 00	90 00
3	*a*	∝0	100	90 00	90 00	90 00	90 00
4	*m*	∝	110	90 00	50 50	90 00	50 49
5	λ	2∝	210	90 00	67 50	90 00	67 49
6	Π	$\frac{5}{3}$∝	530	90 00	63 46	90 00	63 56
7	η	$\frac{3}{2}$∝	320	90 00	61 38	90 00	61 28
8	χ	∝3	130	90 00	22 10	90 00	22 14
9	*d*	$\frac{1}{2}$ 0	102	90 5	38 49	90 00	38 51
10	*o*	01	011	0 13	52 38	0 00	52 43
11	*z*	1	111	50 51	64 27	50 49	64 18
12	*f*	$\frac{1}{3}$	113	50 45	34 36	50 49	34 43

CALCITE FROM TERLINGUA, TEXAS.

Occurrence.—Excellent specimens of calcite have recently been found in the Terlingua cinnabar mine and a couple of them have been presented to the department by Mr. Wilke. This mine is the one from which the new mercury minerals Eglestonite, Terlinguaite, and Montroydite came.[14] The specimens are reddish calcareous rock coated with a layer of clear lustrous calcite crystals, which are interesting because of the number of rarer forms present. The crystals have a pale yellowish tinge and occasionally include specks of cinnabar. A few larger crystals of a second generation occur lying upon the calcite coating, which have the same habit as those of the first generation. The crystals forming the coating are fairly uniform in size, averaging 5 mm. in diameter, and all stand vertically on the rock, showing the complete upper half and portions of the lower half of the crystals. The few crystals of the later growth lie more on their sides and show both ends. They have a deeper yellowish tinge.

Habit.—One habit characterizes all the crystals, namely, a large negative rhombohedron −2R with much smaller faces of the other forms grouped about its edges. Fig. 3 shows the general habit and most of the forms.

Forms.—The forms observed on the crystals are given in the following table. Notwithstanding the great number of forms possessed by calcite, a new scalenohedron 3R $\frac{2}{9}^{3}$ is present.

[14] Amer. Journ. Science, 1903 (4), 16, 251-261.

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Since it is so general to think of Naumann's symbols for rhombohedrons and scalenohedrons, they are also added in the table. The letters for the forms are those used by Goldschmidt in his Winkeltabellen, and by Palache for the forms on the calcites from Lake Superior.[15] To avoid repetition the average of the measurements with the calculated angles are given in the same table.

No.	Letter	Gdt.	Symbol Bravais	Naumann	Measured ϕ	Measured ρ	Calculated ϕ	Calculated ρ	No. of Meas.
1	*b*	∞	$10\bar{1}0$	∞R	30° 00′	90° 00	30° 00	90° 00	8
2	π	10	$11\bar{2}3$	$\frac{2}{3}$ P 2	0 16	29 37	0 00	29 40	2
3	ϕ.	—2	$\bar{2}021$	—2 R	29 58	63 01	30 00	63 07	14
4	δ.	$-\frac{1}{2}$	$\bar{1}012$	$-\frac{1}{2}$ R	30 00	26 08	30 00	26 15	1
5	Σ.	—11.11	$\bar{11}.0.11.1$	—11 R	29 55	84 40	30 00	84 44	6
6	ϕ.	—14.14	$\bar{14}.0.14.1$	—14 R	29 56	85 40	30 00	85 51	4
7	*p*.	1	$10\bar{1}1$	R	29 58	44 36	30 00	44 36	13
8	*R*.	2	$20\bar{2}1$	2 R	30 00	63 11	30 00	63 07	1
9	*t*:	$1\frac{1}{4}$	$21\bar{3}4$	$\frac{1}{4}$ R^3	11 06	33 16	10 53	33 07	13
10	*g*:	$1\frac{1}{3}$	$52\bar{7}9$	$\frac{1}{3}$ R $\frac{7}{3}$	13 05	34 08	13 54	34 23	2
11	*e*:	$1\frac{1}{2}$	$41\bar{5}6$	$\frac{1}{2}$ R $\frac{5}{3}$	19 31	37 05	19 06	37 00	15
12	*B*:	$\frac{7}{5}$ 1	$17.2.\bar{19}.15$	R $\frac{19}{15}$	24 06	49 30	24 30	49 56	3
13	*C*:	$\frac{3}{2}$ 1	$71\bar{8}6$	R $\frac{4}{3}$	22 54	51 55	23 25	51 08	2
14	*E*:	$\frac{7}{4}$ 1	$51\bar{6}4$	R $\frac{3}{2}$	21 10	53 51	21 03	53 56	4
15	*F*:	21	$41\bar{5}3$	R $\frac{5}{3}$	19 07	56 06	19 06	56 26	2
16	*K*:	41	$21\bar{3}1$	R^3	10 42	69 06	10 53	69 02	13
17	*M*:	51	$7.4.\bar{11}.3$	R $\frac{11}{3}$	8 00	73 26	8 57	72 30	1
18	*O*:	61	$8.5.\bar{13}.3$	R $\frac{13}{8}$	7 16	75 14	7 35	75 00	6
19	*P*:	71	$32\bar{5}1$	R^5	6 21	76 46	6 35	76 54	4
20	*U*	62	$10.4.\bar{14}.3$	2 R $\frac{7}{5}$	14 25	76 42	13 54	76 19	2
21	*X*:	10.3	$16.7.\bar{23}.3$	3 R $\frac{23}{9}$	12 06	81 39	12 44	81 32	5

Prisms.—The only prism present is the unit form, ∞ R. It is represented by small triangular faces which are perfectly developed and gave very bright signals.

Pyramids.—On one crystal two bright faces of the second order pyramid $\frac{2}{3}$ P2 occur. It was not observed on the other seven crystals measured.

Positive rhombohedrons.—The unit rhombohedron + R is present on all of the crystals. The faces are narrow but very perfect. They are longer on the crystals of the first generation than on those of the second. Minute faces of a steep rhombodedron occur on some of the crystals, and one reading showed the

[15] Mich. Geol. Survey, 1898, 6, Part 2, 161-184.

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rare form + 2R to be present. This form has only been observed before by Palache, on the Lake Superior calcites. Some of the crystals have a still steeper form in this zone, perhaps + 4R, but no readings could be obtained to substantiate it.

Negative rhombohedrons.—The predominating form on the crystals is — 2R. The faces are very bright and permitted of accurate polar orientation of the crystals. The rhombohedron — ½R which is so common for calcite is practically wanting on these crystals. It was only observed once, and then as a mere line face on the edge formed by the two faces of the scalenohedron ½R⅝. The steep form — 11R occurs on all the crystals in very narrow faces. It occasionally grades into still steeper rhombohedrons, only one of which, — 14R, could be definitely established.

Positive scalenohedrons.—All of the scalenohedrons are in the positive sectant and are characteristically different from the rhombohedrons in having either striated, dull, or etched faces. The forms ¼R^3 and ½R⅝ are present on all the crystals, while the form ⅓R⅞, which lies between them, occurs seldom. The faces of these scalenohedrons are characteristically striated, the fine lines being parallel to the zonal edge with the unit rhombohedron. The scalenohedrons lying below the unit rhombohedron are not as perfectly developed as the other forms on the crystals. They tend to grade into one another with no sharp boundary lines between and readings could be obtained for several doubtful forms, but only those which could be definitely established are included in this description. The forms R$^{19}/_{35}$, R⅖, R⅜, and R⅝ are all very narrow, and of these R⅖ is the commonest. A measurement was obtained which denoted the possibility of R⅞, but as this would be a new form and could not be verified on other crystals it is omitted.

The common scalenohedrons R^3 and R^5 are present on all the crystals, and between them a series of forms occur of which R$^{11}/_3$ and R$^{13}/_3$ were established. R$^{14}/_3$ which has only been observed on the Lake Superior calcites is a doubtful form on these crystals. The faces of these scalenohedrons are generally cross-sected by fine parallel striations, but these did not prevent good measurements. The rare form 2R⅞ is present on all the crystals, but

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always as dull faces, so that good readings could not be obtained.

The new form $3R^{2}/_{3}$ seems to be present on all of the crystals, but it is often rounded slightly, so that good measurements could not always be obtained. The average angles are close to the best measurements and the form is well established.

Mineralogical Laboratory, University of California,
January, 1906.

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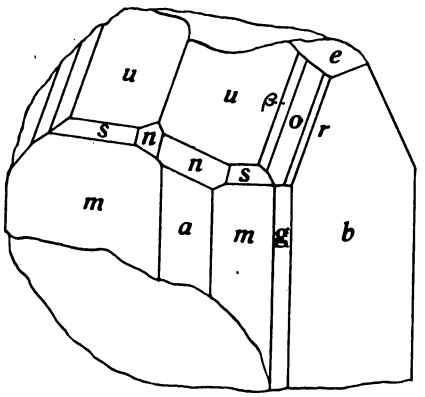

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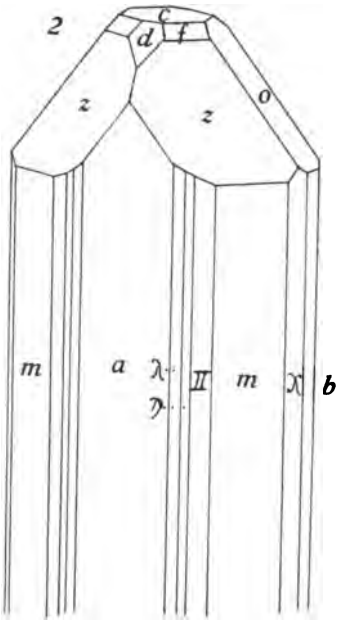

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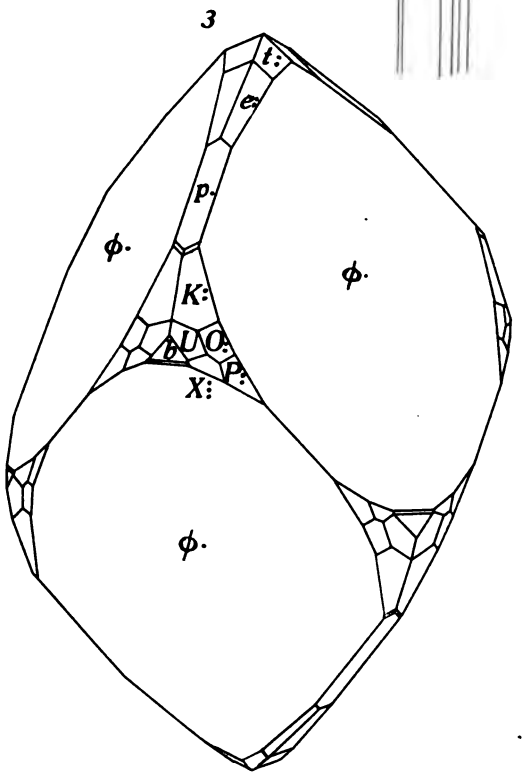

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UNIVERSITY OF CALIFORNIA PUBLICATIONS

BULLETIN OF THE DEPARTMENT OF

GEOLOGY

Vol. 5, No. 7, pp. 95-144, Pls. 11, 12. ANDREW C. LAWSON, Editor

THE FOSSIL FISHES OF CALIFORNIA

WITH SUPPLEMENTARY NOTES ON OTHER SPECIES OF EXTINCT FISHES.

BY

DAVID STARR JORDAN,
President of Stanford University.

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INTRODUCTION.

In the present paper is given an annotated list of the species of fossil fishes recorded from the rocks of California, with descriptions of a number of new species. In addition to this, certain notes on species found elsewhere are appended.

The sole paper treating of the fossil fishes of California is by Professor Louis Agassiz. It is entitled, "Notice of Fossil Fishes Found in California by W. P. Blake." It is in the American Journal of Science and Arts for 1856, pp. 272–275. In it ten species of fossil sharks are recorded from Tertiary (Miocene) deposits, mostly on Ocoya or Posé Creek, in Kern County. This article with a few verbal changes and a page of engravings is reprinted in the appendix to Lieutenant Williamson's Report on Explorations in California, U. S. Pacific R. R. Survey for 1853, pp. 313 to 316, pl. I.

In the present paper the Californian material examined is as follows:

1. Series of fossil fishes from the Museum of the University of California, received through Professor John C. Merriam.

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These are from (*a*) Upper Triassic deposits at Bear Cove, Brushy Slope, "Camp Wemple," and North Fork in Shasta County; (*b*) from a fresh-water deposit of marl rock of Miocene age in a cut in the Canal near Truckee, California; (*c*) from a hard dark brown argillaceous sandstone belonging to the Chico formation of the upper Cretaceous, near Martinez, California; and (*d*) from Miocene deposits six miles north of Santa Ana, in Orange County; also with these is a collection from Quaternary deposits near Fossil Lake, Oregon.

2. An enormous collection of sharks' teeth belonging to the California Academy of Sciences, obtained by Mr. Frank M. Anderson, Curator of Palæontology in the California Academy of Sciences, from Lower Miocene deposits at Barker Ranch, there collected by Mr. John Barker, from a point four miles east of Oil City in Kern County and in Kern County, from Pliocene (San Pablo) deposits, Coalinga and Zapata Chino Creek in Fresno County, the same horizon as that from which Dr. Blake sent specimens to Professor Agassiz in 1855. This collection, with the exception of a few duplicates reserved for the collections of Stanford University and the University of California, was destroyed by the fire of April 18, 1906.

3. A collection of fossil fishes made from Miocene sandstones and marles about Soledad pass, and from Brown's Cañon above the Soldiers' Home near Santa Monica, in Los Angeles County, by Dr. Stephen W. Bowers of Los Angeles (recently deceased). These belong to the Museum of Stanford University.

4. A collection of sharks' teeth from the Santa Monica range near Santa Monica and Port Los Angeles, the property of Dr. J. J. Rivers. These rocks are regarded as of Pliocene age.

5. A small collection from Miocene deposits on Santa Anita Ranch, five miles west of Gaviota, in Santa Barbara County, brought to the University of California by Mr. W. J. Raymond.

6. A small collection made in Miocene marls near Shorb, in Los Angeles County, by Dr. Ralph Arnold and Mr. Delos Arnold.

7. A collection of fragments of *Etringus scintillans* from Monterey shales on Brea Cañon, Orange County, made by Mr. W. O. Clark of the U. S. Geol. Survey.

It may be premised that Palæontology is never an exact science, and that almost all conclusions and determinations in

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this paper are open to some question, the degree of which is scarcely fully indicated by the query marks used by the author.

Family HYBODONTIDÆ.

Genus HYBODUS Agassiz.

1. *Hybodus shastensis* Wemple, Bull. Dept. Geol., Vol. V, p. 73.

Three small teeth of a species of *Hybodus* from the upper Triassic of the Shasta region at the locality known as Bear Cove, in the Museum of the University of California. One of these, No. 10,255, has been made the type of a species called *Hybodus shastensis,* by Miss Edna M. Wemple. This specimen has a conical crown, rising from a broad lunate root, of which the breadth is twice the height of the crown. The crown is rather pointed, nearly erect, and on one side of the base are two much smaller cusps well separated from the large one with a slight rounded denticle between. Two similar cusps exist on the other side, according to Miss Wemple, but they are more or less obscured in the specimen, which is partly imbedded in hard, black calcareous rock. The whole crown of the tooth is striated, rather coarsely when we consider the size of the tooth. This species is certainly a *Hybodus* and it is allied to the European *Hybodus grossiconus* of Agassiz.

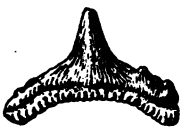

Fig. 1. *Hybodus shastensis* Wemple. Upper Triassic, Shasta County, California. Type specimen.

The following description is from Miss Wemple's manuscript:

"Type, one detached tooth, No. 10,255, Univ. Cal. Col. Vert. Palæ. From the Upper Triassic at the west end of Bear Cove, Shasta County, California.

"The crown supports a high, robust, principal cone with a broad base. There are five lateral denticles. The upper portion of the principal cone is rather sharply narrowed. The lateral denticles, two on one side and three on the other, all are short and robust with narrowed tips.

"The sides of the principal cone and all of the denticles are cut into numerous strongly marked ridges. The crown overhangs the base slightly. The base is wide, with one margin deeply scal-

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loped. There are distinct perforations between the ridges of the serrated base. Directly in front of the first of the cluster of three lateral denticles there is a depression in the contour of the tooth corresponding with the depression in front of the first denticle on the opposite side of the cone."

A second tooth, very small, No. 10,196, is much like the type of *Hybodus shastensis,* but the main cusp is much lower, and there are no lateral cusps. This is also from Bear Cove, and probably belongs to the same species.

A third tooth, still smaller, and doubtless from the outer edge of the jaw, has the median cusp reduced to a rounded, striated prominence; the other cusps not developed.

Still another specimen (No. 1,068), received later, seems also to belong to *Hybodus shastensis.* The general form is similar, but the base of the crown has a slightly reëntrant angle or concavity when it meets the root. Two smaller cusps are evident on one side of the base; the other side is broken.

A part of a fin-spine (10,193) is also preserved from the same region. It is smooth in outline, finely striated and rapidly tapering upward. On the same piece of rock is a fragment of a scale of *Holoptychus.*

Besides these teeth are numerous tubercles probably belonging to the same species of *Hybodus.* On one specimen (No. 10,204), from "Camp Wemple," there is a series of rounded, bluntly conical tubercles coarsely striated. There are about eighteen of these in a lengthwise series of nearly two inches, and three or four in a crosswise series of nearly half an inch. These may be part of the rough shagreen of the skin of the shark *Hybodus.* Similar but larger tubercles are figured by Woodward from the head of *Hybodus delabechei.* Another specimen contains a series of five rounded, blunt, equal tubercles arranged in a regular series. This may be from the posterior edge of a fin-spine. This is from Bear Cove (No. 10,195). Still another, about $\frac{1}{2} \times \frac{1}{4}$, is evenly covered with small, close set, very blunt, smooth tubercles. This is No. 10,192, from Brushy Slope. It may be a fragment of shagreen. The fact that its outline is rounded and that the median tubercles are largest renders this uncertain. One tubercle is 1–3 inch in diameter, six-angled, with a median pit. This looks like a buckler from the back of a ray.

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Genus ACRODUS Agassiz.

This genus differs from *Hybodus* in having the teeth rounded, without cusps.

2. *Acrodus wempliæ* Jordan, new species.

Six teeth of a species of *Acrodus,* from the Triassic of the Shasta region at Bear Cove and North Fork, are in the University of California Collection. These are found in the same black calcareous rock as *Hybodus shastensis.* The type of this species is a long and narrow tooth, ¾ inch in transverse length, slightly curved and compressed, tapering each way, crossed by very fine wrinkles, about twenty-five on each side of the middle; no distinct median ridge. The species is near the European *A. keuperinus* and *A. hirudo.* Compared with these, and especially with *Acrodus gaillardoti* Agassiz, the teeth are narrower, with finer striæ, and no median ridge or furrow. All the other specimens (Nos. 10,190, 10,198, 10,201, 10,202, 10,203) are more or less broken, but all agree in general type.

Fig. 2. *Acrodus wempliæ* Jordan. Triassic of Shasta region. Type specimen.

Another specimen of a tooth of *Acrodus,* received later (No. 1,068), seems to have come from the mouth of the same species of shark. It is, however, somewhat different in form and of a more specialized character. There is a low median elevation at the center of the tooth, almost amounting to an obtuse cusp. At this point the two halves of the tooth meet with a distinct angle. This central part of the tooth is thickened, deepened and rounded, and the striæ radiate from its center. As the sides of the tooth are formed and striated very much as in the type of *Acrodus wempliæ,* I think this probably a more specialized tooth of the same species.

The species is named for Miss Edna M. Wemple of the University of California, who first recognized the species.

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Family HEXANCHIDÆ.

Genus HEPTRANCHIAS Rafinesque.

3. *Heptranchias andersoni* Jordan, new species.

Of this species, apparently undescribed, I have four teeth from Barker's Ranch, Kern County, collected by Mr. F. M. Anderson, placed in the Museum of the California Academy of Sciences. Three of them are apparently submedian teeth from the upper jaw. Each of these teeth consists of two equal cusps, turned somewhat outward and almost equally so. In both of these the anterior cusp is rather coarsely serrated at base. The other tooth is a lateral one from the lower jaw. It consists of eight cusps, the first not especially enlarged, the others progressively smaller, the last three more rapidly reduced; edges of the cusps entire. The species is probably a *Heptranchias*, but it is possibly a *Hexanchus*. The teeth have more cusps than in the living species, *Heptranchias maculatus* of the coast of California. One of these specimens only escaped the fire of 1906.

Fig. 3. *Heptranchias andersoni* Jordan. Miocene of Kern County, California. Type specimen.

The species is named for Mr. Frank M. Anderson, Curator of Palæontology in the California Academy of Sciences.

Family CARCHARIIDÆ.

Genus GALEOCERDO Müller & Henle.

4. *Galeocerdo productus* Agassiz, Agassiz, Am. Jour. Sci. Arts, 1856, p. 273; U. S. Pac. R. R. Surv., p. 314, pl. 1, f. 1–6.

This species is said to differ from the extinct *Galeocerdo aduncus* of the Swiss Eocene, "chiefly in having the anterior margin of the tooth less arched, with much more minute crenulations, and the serrations on the basilar margin far smaller."

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In the collection of Mr. Anderson from Barker Ranch and from near Oil City in Kern County are about thirty specimens of this species; some minute, others reaching a length of two-thirds of an inch. The largest tooth is sharp, subterete, and somewhat

Fig. 4.

a. Galeus (zyopterus?). Pliocene of Temescal Cañon.
b. Galeocerdo productus? Miocene of Kern County, California.
c. Galeocerdo productus? Miocene of Kern County, California.
d. Chiloscyllium? Miocene of Kern County, California.
e. Galeocerdo productus. Miocene of Kern County, California.

flexuous, convex on the outer margin, with about twenty-five very fine crenulations, the tip entire. On the inner margin the tooth is deeply notched, so that the outline presents nearly a right angle with its base, both basal part and vertical margin being fully crenulate, having about ten fine crenulations. The width of the base is about equal to the height of the tooth. Some of the outer teeth are almost entire. Some of these have the tooth reduced to a rather slender hook, not serrated, and on a very broad root. The peculiar twist of the tooth in this species is characteristic.

Another tooth of this genus from near Oil City has the basal crenulations or denticles on the root very strong, while those on the outer margin are scarcely evident. The tooth is low and very broad, the tip strongly turned outward. It resembles *Galeocerdo aduncus* more closely than the others, called *G. productus.* It is probably of the same species as those called *G. productus.*

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Genus GALEUS Rafinesque.

(*Galeorhinus* Blainville: *Galeus* Cuvier.)

5. *Galeus* (*zyopterus* Jordan & Gilbert) ?

A tooth belonging to a species of *Galeus* is in the Rivers' Collection from the Pliocene of Temescal Cañon, in the Santa Monica Mountains. It is similar to the teeth of the living "Soup-fin shark," *Galeus zyopterus* of the California coast, although the tooth is more nearly erect and less notched on the outer margin than are most of the teeth in that species. The tooth is small, narrowly triangular, turned moderately outward, the base with five small cusps on the inner margin, the cusp nearly entire.

Genus CARCHARIAS Rafinesque.

(*Carcharhinus* Blainville: *Carcharias* Cuvier.)

6. *Carcharias antiquus* (Agassiz).

(*Prionodon antiquus* Agassiz, l. c. p. 273; Ocoya Creek.)

To this species we refer two small teeth from near Oil City in the lower Miocene.

The one is triangular, strongly bent outward, the outer margin nearly vertical, but not forming a right angle with the root. The inner margin is nearly straight. The tooth is everywhere serrulate, the inner margin slightly so, the outer margin more distinctly, the serræ larger toward the base. The tooth is about 1–3 inch in height. The other tooth is narrower, more erect, with wider base, wider than the tooth, and slightly cordate.

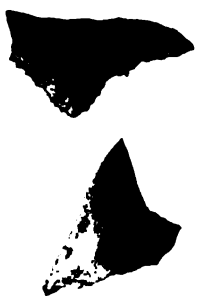

Fig. 5. Upper figure *Carcharias* sp. Miocene, Oil City, California. Lower figure *Carcharias antiquus* (Agassiz). Miocene of Kern Co., California.

Agassiz states that "a transverse section of the fossil under consideration moreover shows these teeth to have a central cavity as in those of the whole tribe of *Carcharias*."

According to Agassiz, the larger and broader specimens of this species have the edges of the teeth serrated, especially at the base, while the narrower ones are smooth and sharp. I am not quite sure that these

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specimens belong to Agassiz's species. They are broader than shown in Agassiz's figures, more erect and more strongly serrate. Possibly Agassiz's figures were drawn from teeth from nearer the side of the jaw.

7. *Carcharias* species.

A tooth which I am unable to place is broadly triangular, thick and blunt with a broad base, longer on the outer margin. The crown is convex anteriorly, and flat behind. The tooth is everywhere very coarsely serrate, eleven teeth on the outer margin of the crown, about eight on the inner margin, and six on the expanded base. It is about ¼ inch in height, and was found in the lower Miocene near Oil City.

Agassiz figures nothing like it. It is perhaps a lateral tooth of some species of *Carcharias* having the teeth much more strongly serrated than is the case in *C. antiquus.*

A second specimen from Barker Ranch seems to belong to the same species. It is larger, rather narrowly triangular, suberect, flat on the posterior side, and with the edges rather strongly serrate. The root is lost.

Genus HEMIPRISTIS Agassiz.

8. *Hemispristis heteropleurus* Agassiz.

(Agassiz, l. c. p. 274; Ocoya Creek.)

Of this genus, Agassiz had a single tooth from Ocoya Creek. He separates the species from *Hemipristis serra* of the European Tertiary by "the marked inequality of the serration of the hinder margin when compared with that of the anterior margin of the tooth." This difference, as Agassiz indicates, is a very slight one, and in fact we doubt if it exists, and there is no obvious reason for regarding the California species as different from *Hemipristis serra.*

In Mr. Anderson's collection, in the Museum of the California Academy of Sciences, are two specimens of this species from the "Northwest of Barker Ranch on the Kern River," and one from near Oil City. The largest is nearly an inch high, the other shorter. In this genus the teeth are erect, strongly curved outward, both margins rather convex, with a slight reëntrant angle

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on the inner margin. The tip is narrowed, sharp and entire. Below the tip both margins are strongly serrated, the serræ or denticles being long and narrow, but coalescent at base. There are

Fig. 6. *Hemipristis heteropleurus* Agassiz. Miocene of Kern County, California.

about twelve denticles on the crown of the tooth, and on the inner margins there is a notch between the crown and the root with smaller denticles. Similar denticles exist on the root. In this species the denticles of the inner margin are a shade longer than those on the outer, a trait supposed to mark the Californian species, *Hemispristis heteropleurus.*

The genus *Hemipristis* has been regarded as extinct, but Dr. Woodward identifies it with *Dirrhizodon* Klunzinger, of the Red Sea.

9. *Hemipristis chiconis* Jordan, new species.

In a hard sandstone rock of dark brown color, belonging to the Chico division of the upper Cretaceous, near Martinez, obtained by Dr. John C. Merriam, there is a small tooth of a different species of *Hemipristis.* The tooth is subtriangular, about as broad as high, the inner edge convex, the outer nearly straight, with an incurved angle. The tip of the tooth is without denticles. On the inner edge there are about twelve of these serra-

Fig. 7. *Hemipristis chiconis* Jordan. Chico Cretaceous near Martinez, California.

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tions, rather larger than in *H. hereopleurus,* and without break at the base of the crown. The outer edge of the tooth is partly imbedded, and I can trace no denticles on it. The median line of the tooth has a rather conspicuous ridge as in *Galeus,* to which genus this tooth bears some resemblance.

Family LAMNIDÆ.

Genus LAMNA Cuvier.

10. *Lamna clavata* Agassiz.

The genus *Lamna* is known from *Isurus* by the presence of one or two small denticles at the base of a flexuous tooth, the edges of which are entire.

According to Agassiz, the species is allied to *Lamna cuspidata* of the European Miocene, differing in its shorter and narrower crown, in which it agrees with *L. hopei* of Sheppy. The crown is less arched than in the latter. The posterior surface is smooth as in *Lamna cuspidata.*

Fig. 8. *Lamna clavata* Agassiz. Miocene of Kern County, California.

Three finely preserved teeth supposed to be from Miocene deposits in Kern County, in the Museum of Stanford University, the exact locality not recorded. Length, 1¼ inches. Breadth of

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root, about two-thirds height of crown. Larger teeth with a sharp denticle at base on each side. These are absent in the smaller teeth, which, like an *Isurus,* has no denticles. Agassiz figures this species as without denticles.

11. *Lamna ornata* Agassiz.

(Agassiz, l. c. p. 275; Navy Point, Benicia.)

Of this species, Agassiz figures only a small part of the base of the cusp. This is much more strongly striate than *Lamna clavata.* I have not seen *Lamna ornata.*

Agassiz says of this species that it is smaller than *Lamna elegans* of Europe. The tooth "tapers more gradually, while in *Lamna elegans* it tapers more suddenly near the top, and the folds of the enamel on the inner side of the tooth are coarser. The base of the tooth is more compressed than the *L. elegans,* in which respect the tooth resembles more *L. acuminata.*"

12. *Lamna* species.

In a hard sandstone of the Chico formation are two small teeth, one very long and flexuous, another shorter, narrowly triangular, with large basal denticles on one side. These belong to a species of *Lamna* apparently related to the one figured by Mr. Stewart as *Lamna appendiculata* from the Cretaceous of Kansas. Its basal denticle is very much larger than in *Lamna clavata,* while the tooth itself is broader and less flexuous. The tooth is sharper and more erect than in *Lamna appendiculata.* It may be found that this species is referable to *Odontaspis.* We find no figure which quite corresponds to its form.

Genus ISURUS Rafinesque.

(*Oxyrhina* Agassiz.)

13. *Isurus planus* (Agassiz).

(*Oxyrhina plana* Agassiz, l. c. p. 275; Ocoya Creek.)

In this genus the teeth are more or less elongated, entire-edged, without basal denticle, the outer teeth much broader and shorter than the others, the median teeth more or less slender and flexuous, suberect, the outer teeth more or less hooked outward and with a knife-like upper edge. On account of variations in

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forms of the teeth, it is not easy to determine species in this genus.

This species is distinguished by the flatness and breadth of the crown of its teeth. The inner edge of the tooth is quite flat, the outer or front not much convex. We refer to *Isurus planus,* about 200 specimens of various sizes, but all relatively short and broad. These are from Barker Ranch, in Kern County, and from near Oil City. Some are nearly erect, and narrowly triangular.

Fig. 9. *Isurus planus* (Agassiz). Miocene of Kern County, California.

Some which we suppose to be outer teeth are very much more curved, and have a marked reëntrant angle. These would seem at first sight to indicate a distinct species, but we are convinced that both straight and hooked teeth came from the same shark. The root in *Isurus planus* is very broad, and its basal margin is but little curved, usually not crescent-shaped. The largest teeth of this type are one and one-half to two inches in length. The largest specimen of all, two and one-fifth inches high, was ob-

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tained by Dr. Bowers on Carrizo Creek, San Diego County, near the Mexican line. This tooth is flat, narrowly triangular, and nearly erect.

14. *Isurus tumulus* Agassiz.

(*Oxyrhina tumula* Agassiz, l. c. p. 275; Ocoya Creek.)

Many specimens of *Isurus,* large and small, seem to belong to a species of *Isurus* distinct from *Isurus planus.* The scanty description of *Isurus tumulus,* characterized by "the extraordinary

Fig. 10. *Isurus tumulus* (Agassiz). Miocene of Kern County, California.

thickness of the root of the tooth," seems to apply to this form. We have upward of 100 specimens obtained by Mr. Anderson from the Miocene of Barker Ranch, and especially from the Miocene four miles east of Oil City, with large examples from near Santa Ana. In some of these the tooth is two and one-half inches in height, a size enormous for an *Isurus.* The crown is rather slender, narrowly triangular sometimes, somewhat flexuous, the outer teeth broadly triangular, all the teeth much more convex in section than in *Isurus planus,* and less flat. The base is thicker, usually broadly lunate. None of the teeth are so strongly hooked

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as the lateral teeth of *I. planus*. The chief distinction rests in the basal thickness of the crown of the tooth, measured from front to back. None of these teeth show a strongly curved crown or a re-entrant angle on the outer margin. There is no median ridge as is seen in *Isurus mantelli*, a related species from the Cretaceous of Europe.

The following notes are on teeth from near Santa Ana:

These teeth are very large, the largest teeth being two inches long. The crown is flexuous, curved backwards in the median teeth, curved forward in the lateral ones. The root is heavy, little

Fig. 11. *Isurus tumulus* (Agassiz). Miocene of Santa Ana, California.

cordate below, its form varying in the different teeth. Some teeth are knife-like, the crown not one-third higher than the breadth at base, the form suggesting that of *Isurus planus*. Other teeth, supposed to be median, are less flattened, and nearly half higher than broad at base. All are erect or nearly so, with entire edges. Some of the smaller teeth are more curved, and more acuminate.

Some of the teeth from near Oil City are still larger, with thicker base, but are otherwise similar. One large tooth with a thick crown and heavy base is curved strongly outward, with a knife-like margin. This is probably an outer tooth of the same species, but no teeth quite like this are found in the living species

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of *Isurus*. The still more curved outer teeth of *Isurus planus* are not found in the relatively small species which represent the genus in the waters of to-day. These huge Miocene species must have reached a length of thirty or forty feet. The present species are from five to fifteen feet in length.

It will not be possible to distinguish all the teeth of *Isurus tumulus* from those of *Isurus planus*. There can, however, be little doubt that we have to deal with two distinct species.

15. *Isurus smithii* Jordan, new species.

Numerous teeth from the Barker Ranch and Oil City Miocene in the collection of the California Academy of Sciences differ considerably from these two species of *Isurus*. The largest tooth is more than an inch long,—slender, sharp, and flexuous. The

Fig. 12. *Isurus smithii* Jordan. Miocene of Kern County, California. Type specimen.

base is very narrow, about two-fifths the height of the tooth. Other teeth are shorter and broader, being probably from nearer the side of the jaw. These teeth resemble those of *Lamna clavata*, but they are more tapering, more sharply pointed, and without basal denticle. The base of the tooth is almost equally cordate.

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In *Isurus planus* and *Isurus tumulus,* the base of the tooth is much broader, at least two-thirds the height of even the largest teeth.

Three other teeth of this species are from a point three miles west of Coalinga, in Fresno County. These are from rocks of the San Pablo formation, in the Pliocene. It is barely possible that these teeth are median teeth from the jaws of *Isurus tumulus,* but at any rate it seems best to give them a distinctive name.

The species is named for Dr. James Perrin Smith, palæontologist of Stanford University.

16. *Isurus desorii* (Agassiz) ??

Another species of this type is represented by a single specimen in the sandstone of the Chico formation of the Upper Cretaceous. It is long and slender, flexuous, without basal denticles. The base seems to be narrower. We cannot distinguish the specimen from *Isurus smithii,* though it is found in a much older formation. It much resembles *Isurus desorii* (Agassiz) of the European Cretaceous, with which it may be provisionally and very doubtfully identified.

Genus CARCHARODON Andrew Smith.

17. *Carcharodon rectus* Agassiz.

(Agassiz, l. c. p. 274; Ocoya Creek.)

Agassiz separates this species from *Carcharodon angustidens* by the absence of "accessory points on each side at base." *Carcharodon angustidens* belongs to a different section of the genus, differing from *Carcharodon* by the presence of basal denticles, as *Lamna* differs from *Isurus.* Among our many specimens of *Carcharodon* I find none identifiable as *Carcharodon rectus.* The nearest is the specimen from Oil City, called below *Carcharodon branneri.* The figure of *C. rectus* shows a tooth about two inches high, rather narrowly triangular and flat, with a serrated protuberance on each side at base corresponding to a lateral denticle. The tip of the tooth is entire. The serrations are small, close-set, about fifty on each side, besides about eight on each lateral denticle. The edge of the tooth is straighter than in

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C. branneri. In *C. branneri* the tooth is more curved, it is serrated on both sides to the point, and there is no trace of lateral denticle or protuberance.

This species, *Carcharodon rectus,* is perhaps nearer than any of the others here named to the living man-eating shark, *Carcharodon carcharias,* now found on the California coast. In that species, the serrations are fine, and range from ten to thirty-five in number on the different teeth. For the following count made by Mr. Samuel Garman on the jaws of this species, I am indebted to Mr. Barton A. Bean. Mr. Garman says:

"The count of serrations on right-hand jaws of *Carcharodon,* from the tenth tooth toward the symphysis, runs as follows:

UPPER.

10	9	8	7	6	5	4	3	2	1
0|10	10|13	13|18	21|20	27|25	25|28	23|27	26|25	30|32	28|25

LOWER.

8	7	6	5	4	3	2	1	Outer.
15|	18|	16|	20|21	19|20	21|22	31|35	25|25	Inner.

"I have counted all serrations possible, so the numbers are not too small, but find very doubtful places and much variation. Thus some that might be called single denticles have two or three subdivisions, and toward the ends of the serrations the denticles and notches fade away so that one can hardly say where they end."

18. *Carcharodon arnoldi* Jordan.

In the Pliocene at Pescadero, San Mateo County, Professor James M. Hyde, of the University of Oregon, has found a tooth of *Carcharodon,* now in the Museum of Stanford University. This is evidently different from *Carcharodon riversi,* having the serrae rather smaller and more numerous, about fifty on each side of the tooth, which is serrated to the tip. The type is about one and one-half inches high, triangular, the crown a little higher than broad, with straight edges, the tooth slightly curved backward, that is, in the line of the axis of the fish. Inner base of crown of tooth with four shallow furrows. No larger denticles at base of the tooth.

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Another specimen of the same species is in the collection of Dr. Rivers from the Quaternary of Rustic Cañon, Santa Monica Range. This specimen is about one and one-half inches high, the form is narrowly triangular, the crown broader than high, the point is strongly curved backward (that is, inward, toward the mouth, so that the tooth seems curved upward when laid flat on a

Fig. 13. *Carcharodon arnoldi* Jordan. Rustic Cañon, Pescadero, California. Two large specimens to left of plate.
Galeocerdo productus Agassiz. Miocene of Kern County, California. Four small specimens to right of plate.

table). The serrae are much more fine and numerous than in *C. riversi*, about fifty in number on the outer margin. The degree to which these numbers are constant is yet to be proved. Dr. Rivers staets that the beds in which this species is found are of the same age "precisely as the hard Pecten beds of San Diego."

The species is named for Dr. Ralph Arnold of the U. S. Geological Survey.

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19. *Carcharodon riversi* Jordan, new species.

In the Pliocene of the Santa Monica Range, Dr. J. J. Rivers has collected two fine specimens of the teeth of a *Carcharodon* with the denticles fewer and coarser than in any other species.

In this species, which I name for Dr. Rivers, the tooth is narrowly triangular, nearly flat, with large root, the crown about as high as broad at base. The serrations are very coarse, there being thirty-five to forty denticles on the outer margin. These extend

Fig. 14. *Carcharodon riversi* Jordan. *a*. Specimens from Santa Monica. *b*. Specimens from Kern County, California.

to the tip of the tooth, and are very much larger than in our other species; base of tooth without lateral denticle. One specimen, the type, is from the Santa Monica Range, near Santa Monica. A second tooth of smaller size is from Port Los Angeles, the locality from which Dr. Ralph Arnold made collections of mollusks. Dr. Arnold regards this deposit as Pleistocene, but Dr. Rivers states that it is most certainly Pliocene. "It is simply an erratic chunk that slid into a gully from a mass above. It belongs to a partly

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metamorphosed series more like the hard rocks of San Diego, but more indurated."

I refer to *Carcharodon riversi,* with some doubt, another tooth collected by Dr. Rivers in Rustic Cañon, in the Santa Monica Range, from Pleistocene deposits. The form and the number of serrations are about as in *C. riversi,* but the serrations are distinctly weaker than in the type of the latter species. This tooth is about one and one-fourth inches high, broadly triangular, the point scarcely incurved. The inner face of the tooth shows six to eight shallow furrows.

To this species I refer also, with some doubt, four specimens from Barker Ranch, in Miocene deposits. I have also an example from Pliocene deposits on Zapata Chino Creek, Fresno County. These teeth are each about an inch long, being smaller than in the other species of *Carcharodon* in California.

This species has thin, flat, straight teeth, narrowly triangular, the base about as broad as the crown is high, and the serrations relatively fine, but few in number; about thirty to forty on the outer margin. As all these teeth are much abraded, it is possible that the serræ in a fresh tooth would be stronger.

20. *Carcharodon branneri* Jordan, new species.

A gigantic tooth of *Carcharodon* is in the Museum of Stanford University, from near Bolinas Bay in California. This tooth is a little over three inches high, broadly triangular on a broad cordate root; the base of the crown is a shade greater than the height of the crown. The tooth is moderately thick, and rather strongly retro-curved, as in *Carcharodon arnoldi.* The edges of the tooth are finely and evenly serrated, the number of teeth being from eighty to one hundred on each side, adding in the count those which are broken off in the type.

The monstrous *Carcharodon megalodon* Charlesworth, of the phosphate beds of South Carolina, has one hundred to one hundred and twenty serrations, as coarse as in *C. riversi,* and there is a suggestion of a median ridge on the tooth, which is less curved than in *C. arnoldi* and *C. branneri.*

A fragment, comprising about one-fourth of a giant tooth of *Carcharodon,* is in the collection of the University of California,

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obtained by Mr. C. H. McCharles from the Miocene six miles north of Santa Ana. It may represent a new species or it may be inseparable from *Carcharodon branneri*. The whole tooth must have been three or four inches high, and its thickness must have been fully an inch, or nearly half the breadth of the tooth at base. The tooth is nearly flat on the inner edge, and very convex on the outer edge. The serræ are small and close set. About

Fig. 15. *Carcharodon branneri* Jordan. Figure to left is type specimen from Bolinas Bay, California; specimen to right is from Santa Ana, California.

fifty are seen on the fragment of one side. This indicates that about one hundred and twenty must have existed on each side, a number comparable to that seen in the huge *Carcharodon megalodon* of the Atlantic Miocene. But in that species the tooth is much flatter and less elevated on the median frontal edge.

Still another tooth, referable to *Carcharodon branneri*, is from Miocene rocks, Oil City. It is two and one-half inches high, rather narrowly trangular, with wavy edges, incurved tip and fine serrations, about seventy in number, on each side.

The following analysis of the characters of the California species of *Carcharodon* may be found convenient:

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(*a*) Teeth flat, little curved, with the serrations mostly 20 to 40 on each side; height of tooth less than two inches; no trace of basal denticle .....
(*b*) Teeth relatively narrow, with moderate serrations. (Species living) .....*carcharias*
(*bb*) Teeth broad, with strong serrations; each tooth with a suggestion of a median ridge .....*riversi*
(*aa*) Teeth more strongly recurved, without median ridge; serræ more than 40 on each side .....
(*c*) Base of tooth on each side, with a serrated protuberance or denticle; tip of tooth entire; serræ 50 to 60 on each side .....*rectus*
(*cc*) Base of tooth without denticle; tip of tooth serrate, like the side
(*d*) Teeth rather narrow, the serræ rather strong, about fifty on each side .....*arnoldi*
(*dd*) Teeth broader, larger, three to four inches high; serræ fine, eighty to one hundred on each side .....*branneri*

For the present these types of teeth may be regarded as belonging to different species of *Carcharodon.*

Family DALATIIDÆ.

Genus DALATIAS.

(*Scymnus* Cuvier.)

21. *Dalatias occidentalis* (Agassiz).

(*Scymnus occidentalis* Agassiz, Am. Jour. Sci. Arts, 1855, p. 72; Ocoya Creek.)

This species is said to be distinguished by "the strong bend backwards of the main point of the tooth, and the distinct and rather marked serration of the edges of the crown." The lower teeth in *Dalatias* are erect, triangular, and serrated. The upper teeth are smaller and more simple.

To this species I refer with some doubt one small tooth from the collection of Dr. J. J. Rivers, in the Pliocene rocks of Temescal Cañon, in the Santa Monica Range. I am not quite sure that this is Agassiz's species, but the identification is probable. This tooth is sharper at the point than is shown in Agassiz's figure; the point is strongly hooked outward, and each side of the base of the tooth has about seven strong denticles; the cusp is nearly entire, the tip quite so. The form of the tooth suggests *Galeocerdo,* but the tooth is much flatter than in the latter. Four similar teeth are in the collection of Mr. F. M. Anderson from four miles east of Oil City.

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It may be found that this species, or any of the others named by Agassiz from the Miocene rocks of the Kern region, is identical with some of the multitude of sharks which have been described in Europe from detached teeth.

Family ECHINORHINIDÆ.

Genus ECHINORHINUS Blainville.

22. *Echinorhinus blakei* Agassiz (l. c. p. 272).

This species "has the main point of the tooth more prominent, and at the same time shorter" than the living *Echinorhinus spinosus,* the marginal denticles being smaller. The teeth in *Echinorhinus* are very oblique, the point turned outward, with several strong denticles on each side of the tooth. I have not recognized this species.

Family SCYLLIORHINIDÆ.

Genus CHILOSCYLLIUM Müller & Henle.

23. *Chiloscyllium* species??

Three very small teeth, narrow, triangular and nearly erect, with the root very wide, its width nearly twice the height of the tooth, and projecting backward so that the tooth rests on a triangular base double-notched posteriorly. The tooth will stand when set erect on the table. The enamel of the crown extends downward on the root in front to its base.

These are from the Miocene of Barker Ranch, in Kern County.

What the genus and species may be is still uncertain. Among recent sharks I find nothing nearer than *Chiloscyllium,* an East Indian genus.

Family AËTOBATIDÆ.

Genus AETOBATIS Blainville.

(*Myliobatis Cuvier; Zygobates* Agassiz.)

24. *Aëtobatis* species.

Professor Agassiz (1 c. p. 275) records the fragment of a tooth of a ray of this genus from Ocoya Creek.

We have also numerous fragments from Miocene of Barker Creek, and from Oil City. The teeth are laterally much elong-

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ate, with serrated or comb-like edge. They vary considerably in breadth, but they must belong to this same species.

Family DASYATIDÆ.

Genus UROLOPHUS Müller & Henle.

25. *Urolophus halleri* Cooper (?).

(Arnold, Pliocene and Pleistocene, Cal. p. 346, San Pedro.)

A spine from the tail of a sting ray was found by Dr. Ralph Arnold in Pleistocene deposits at San Pedro. According to Dr. Gilbert it is not distinguishable from the common living species of the region, *Urolophus halleri.*

Family HOLOPTYCHIDE.

Genus HOLOPTYCHUS *Agassiz.*

26. *Holoptychus* species. (*Holoptychius* of authors.)

Three fragments of Crossopterygian scales, much like those of *Holoptchyus,* are found in Triassic Rocks at Bear Cove in Shasta County. The largest of these is about an inch in diameter, with coarse branching striæ or wrinkles. The ridges are closer together and cover more space than the European species, *Holoptychus flemingi.*

Family CHIROCENTRIDÆ.

Genus XENESTHES Jordan, new genus.

27. *Xenesthes velox* Jordan, new species.

In a rock of Triassic age are the remains of a skull of a fish, apparently belonging to the primitive family of *Chirocentridæ.*

Number 9,098, University of California collection, represents a premaxillary bone over seven inches long. It is armed on its anterior end with a single row of conical bluntish teeth, each with a striated and beveled apex, unequal in size and some of them broken out. The fourteen teeth visible occupy less than one-fourth the length of the bone. Behind the point where the tooth-row disappears in the matrix there is a broad band of blunt pyramidal prichles of much smaller size on the outer surface of the bone. They are close-set almost so as to form a shagreen. There

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are fifteen to twenty of these small, blunt denticles in a cross-series in the band. According to Dr. Merriam's observations, these denticles are not true teeth but are in reality on the outer surface of the bone, and all the bones of the skull are more or less rough with similar denticles.

Besides this part of the jaw, there are large pieces of bones of the skull, each marked by radiating striae. Other fragments,

Fig. 16. *Xenesthes velox* Jordan. (Premaxillary bone.) Triassic of Shasta region, California. Type specimen.

not readily identifiable, occur in the same connection, among others what seems to be a fragment of the dentary having teeth like those of the premaxillary described above. This description is taken from a drawing carefully made by Mr. Bagley, Dr. Merriam's artist, and it is verified on the original specimen by Dr. Merriam.

These fragments seem to indicate a fish allied to *Hypsicormus* and *Protosphyræna,* but the teeth in *Protosphyræna* are very sharp, while in *Hypsicormus* the jaws are much shorter. In the *Ichthyodectinæ* (*Ichthyodectes, Gillicus, Xiphactinus* = *Portheus*) the teeth are in a single row and on the whole the nearest relations of *Xenesthes* seems to be with these genera.

Family ACIPENSERIDÆ.

Genus ACIPENSER Linnæus.

28. *Acipenser medirostris* Ayres?

A scale of sturgeon perhaps of this species was found in Quaternary deposits of Potter Creek Cave by Dr. William J. Sinclair.

Family LEPTOLEPIDÆ?

29. *Etringus scintillans* Jordan, new genus and species.

Head three and one-half in length of body to base of caudal; depth, three and two-fifths. Body compressed, herring-shaped,

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the belly prominent. Head large, rather pointed, the bones apparently thin, but enameled. Scales thirty-five to forty. Mouth large, oblique, the lower jaw prominent, the cleft probably not reaching the front of the large orbit. Vertebrae thirty-seven, apparently well ossified, the centrum large, the neural and haemal spines slightly curved and posteriorly strongly inclined backward. Scales large, quadrate in form, distinctly enameled: prob-

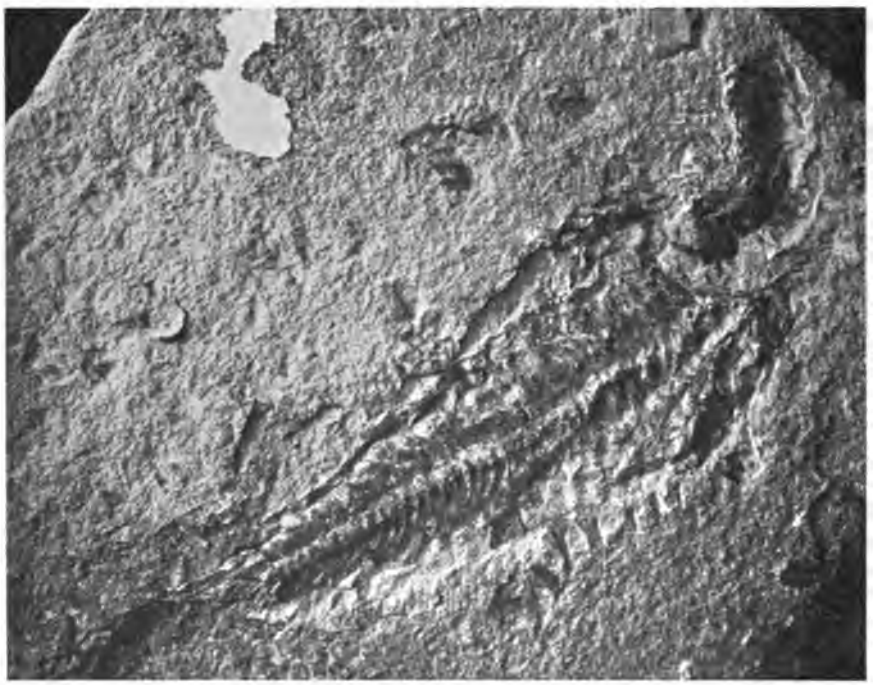

Fig. 17. *Etringus scintillans* Jordan. Miocene of Soledad Pass. Type specimen.

ably about thirty-five in a lateral series; those on the side not greatly deepened; lateral line very distinct, running along the side of the belly, very low, apparently ceasing beyond the tip of the ventral fin. Scales of the lateral line with radiating or digitate ridges, some apparently of this series with a crenate digitate margin.

Dorsal fin apparently nearly median, only traces of anterior rays being left. Ventrals reduced to a trace, apparently nearly

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Fig. 18. *Etringus scintillans* Jordan. Brown's Cañon (No. 29).

Fig. 19. *Etringus scintillans?* No. 29. Brown's Cañon.

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opposite front of dorsal. Pectorals broken, apparently small. Caudal slightly heterocercal, the tips broken. Anal probably long, but no trace of it distinct in this specimen.

The type of this species is a single specimen six inches long. It is imbedded in a hard yellowish shaly sandstone reputed of Miocene Age. The specimen was found by Rev. Stephen W. Bowers in the mountains of the Soledad Pass, about twenty miles north of Los Angeles.

The genus belongs to the primitive types of *Isospondyli,* or herring-like fishes. The well-developed vertebræ leads us to place it among the *Leptolepidæ,* but none of that family, so far as I know, show a lateral line. *Pleuropholis,* a genus of *Pholidophoridæ*, having a lateral line along the side of the belly, differs in having the scales above this line very deep and plate-like. I am therefore obliged to take a new generic name for this California species, the genus being distinguished by the character of the scales and the low position of the lateral line. The name is from ἔτρον, abdomen; ὀγγός, tube.

29. *Etringus* sp.

We refer with doubt to *Etringus scintillans,* a specimen obtained from Brown's Cañon, four miles north of Soldiers' Home, near Santa Monica. This specimen shows a section of the body of a fish about five inches across, just behind the pectoral fin. It shows a mass of cycloid scales less distinctly enameled than in *Etringus,* but apparently of similar nature.

The body of another fish showing only part of the vertebral column and a mass of scales belongs evidently to the same species as the preceding. All the scales on the body are cycloid and not apparently enameled.

30. *Etringus* species.

Around this last named specimen are many large scattered scales one-third to one-half inch in diameter, quadrate, thick and enameled, looking somewhat like the lateral line scales in *Etringus scintillans.* These scales are marked by four to six or more wavy digitate furrows on either side, and the anterior or free edge is more or less crenate-digitate.

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Two smaller scales of this species are imbedded on the rock near the type of *Etringus scintillans.* It is not certain that they came from the same fish. Still another occurs on another block of stone from the same locality.

Another large, loose scale is found associated with the type of *Etringus scintillans.* It is quadrate and entire, marked with fine parallel striations. What it is, I cannot tell.

Etringus species.

Mr. W. C. Mendenhall of the United States Geological Survey has sent a large number of specimens of fragments of fossil fishes found in the Monterey shales of the middle Miocene. These were obtained by Mr. W. O. Clark in Brea Cañon, Orange County, California, about one and one-half miles from Olinda. They are imbedded in rather hard, coarse, blackish, siliceous shales.

Among the specimens are very many detached scales, three sections of the vertebral column, with ribs and one specimen showing part of a caudal fin. The scales are large, cycloid, quadrate in form, some of them showing digitate furrows, and more or less distinctly enameled. The scales are like those of "*Etringus* species" above mentioned.

In the best specimen twenty vertebræ are shown. These are from the middle of the body and are essentially like those of *Etringus scintillans.* The basal bones of the anal fin are very numerous and slender. The specimen showing part of the caudal fin is certainly like the others. The tail is homocercal or nearly so, and the rays are very slender. The form of the fin is not shown.

There is also a vertebral column which looks more herring-like, with twenty-eight vertebræ present, but there are *Etringus* scales lying about it. There is little doubt that all these fragments belong to one species, and this is probably identical with *Etringus scintillans.*

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Family OSTEOGLOSSIDÆ.

Genus PHAREODUS Leidy.

(*Dapedoglossus* Cope.)

31. *Phareodus sp.?*

In a hard rock belonging to the Chico formation of the upper Cretaceous is a very large cycloid scale, nearly an inch in diameter, beautifully striated. It must belong to some of the large Clupeoid fishes, probably to the genus *Phareodus,* which occurs in the Green River Eocene.

Family CLUPEIDÆ.

32. *Clupeoid fish.* A.

Fragments of a Clupeoid or herring-like fish, remarkable for the hair-like slenderness of its ribs and other bones, are found in

Fig. 20. Clupeoid fish (A). No. 32. Miocene of Soledad Pass.

the rocks of Soledad Pass. One of these, lacking the head, has forty-five to fifty slender vertebræ, and a forked caudal fin; the other fins are lost.

33. *Clupeoid fish.* B.

Another herring-like species is found on the Santa Anita Ranch, five miles north of Gaviota. All the specimens from this locality, in a brittle whitish clay shale, are very much broken and unrecognizable. The best preserved is perhaps a species of her-

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ring with about forty vertebræ, which are very small, the ribs slender and hair-like, the head large, apparently with rather long jaws. It is impossible to place either species in any particular

Fig. 21. Clupeoid fish (B). No. 33.

genus. It may possibly prove to belong to the genus *Knightia,* defined on a later page in this paper.

34. *Clupeoid fish.* C.

In the white marls from Shorb are eight specimens or a species of herring-like fish, possibly the same as the one mentioned as A in a paragraph above. The imprints are very shadowy, showing little except the outline and the vertebral column, and the species cannot be identified. In one there are about thirty-five vertebræ. and the dorsal fin is opposite the ventrals.

Family PTEROTHRISSIDÆ.

35. *Pterothrissoid fish?*

The head of a fish, perhaps belonging to the family of *Elopidae* or of *Pterothrissidae* was found in Brown's Cañon, in the

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Santa Monica Range, by Dr. Bowers. It belongs apparently to an elongate fish, with eye very large, about one-fifth the length of the head. The snout is long, and the mouth seems rather large, the upper jaw the longer. There is no trace of teeth. The out-

Fig. 22. Pterothrissoid fish. No. 35. Miocene of Brown's Cañon.

line of the head suggests that of the Japanese fish, *Pterothrissus gissu* Hilgendorf. But there is no evidence that this species belongs to *Pterothrissus* or to any related genus. The eye is much larger than in *Istcus*.

Family COBITOPSIDÆ (?).

36. *Rogenio solitudinis* Jordan, new genus and species.

In the white marl rocks of Soledad Pass are found numerous specimens of a very small fish of a new genus, to which we give the name of *Rogenio*.

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The genus *Rogenio* is characterized by the large head, subequal and elongate jaws, slender vertebræ, and by the fact that the dorsal and anal fins are equally developed, opposite each

Fig. 23. *Rogenio solitudinis* Jordan. Miocene of Soledad Pass. Type specimen.

other, the front of each fin being near the middle of the length of the body.

In *Rogenio solitudinis* the head is about three and three-fourths times in length to base of caudal; the greatest depth is five. The mouth is elongate, oblique, the jaws subequal, apparently extending to below the eye; there are traces of small teeth in the jaws; the snout is pointed. The head is rather depressed abov the eyes; the vertebræ are forty to forty-two, small, about twenty-two behind the vent; no ribs are visible in any specimen. The dorsal and anal are inserted a little behind the middle of body. Each has about ten rays, or at least stand opposite eight to ten vertebræ. The caudal peduncle behind the dorsal is about equal to the length of the fins; the height of the dorsal and anal is about three-fourths the length of the base. The caudal fin is a little shorter than the head, and widely forked. I find no trace of pectorals or ventrals in any specimen. The ventrals are probably abdominal. No trace of scales is found in any specimen.

The type example is one and one-fourth inches in length, very slender and fragile, imbedded in white marl of Miocene Age. There are twenty-nine specimens in Dr. Bowers' collection from Soledad Pass, none of them very perfect, but most of them showing the characteristic form, the opposite dorsal and anal, the slender, almost eel-like, the depth ten times in length, the head and body is vertically flattened. These range in length from one to two inches.

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From Moore's Cañon, in the Santa Monica Range, Dr. Bowers obtained numerous other fragments, none of them well preserved.

Of the known families, the genus *Rogenio* approaches nearest to the *Cobitopsidæ*. The generic name recalls the obsolete name, *Rogenia,* once applied by Valenciennes to the whitebait or very young herring.

37. *Rogenio bowersi* Jordan, new species.

Another specimen, about three and one-half inches long, seems referable to *Rogenio,* but must belong to another species. It shows a head in bad condition, a long vertebral column, the dorsal opposite the anal as in *Rogenio solitudinis,* but very much farther

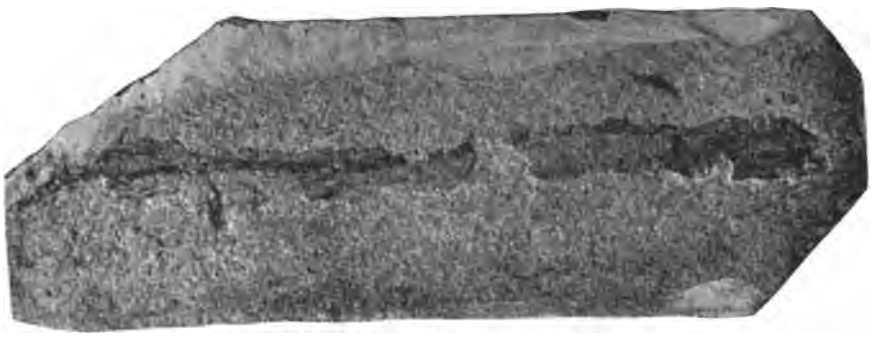

Fig. 24. *Rogenio bowersi* Jordan. Miocene of Brown's Cañon. Type specimen.

back. The head is contained three and one-half times in the space from nape to front of dorsal, while in *R. solitudinis* it goes but one and one-fourth times in the same distance. Fifty-two vertebræ may be counted in this specimen, not very accurately. About thirty-six are before the dorsal, nine beneath it, and seven behind. The end of the column is not preserved, so that we may estimate the total as $36 + 9 + 15 =$ about 60. The body is very slender, almost eel-like, the depth ten times in length, the head about six. The jaws appear to be long, and the form suggests the genus *Stomias.* The dorsal and anal rays are slender, each about ten in number. This specimen is from Soledad Pass, and it may be named *Rogenio bowersi,* for its discoverer, Rev. Stephen W. Bowers, well known as a student of the palæontology of California.

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Family CYPRINIDÆ.

Genus MYLOPHARODON Ayres.

38. *Mylopharodon conocephalus* (Baird and Girard).

From Quaternary deposits in the Potter Creek Cave in Shasta County, Mr. William J. Sinclair obtained various animal remains, described in University of California Publications, American Archaeology and Ethnology, Vol. 2, No. 1, 1904. Among these are pharyngeal bones of three fishes. Among these are *Mylopharodon conocephalus,* a large chub now found in the Sacramento River.

Genus PTYCHOCHELIUS (Agassiz).

39. *Ptychocheilus grandis* (Ayres) ?

Pharyngeals doubtfully referred to this species were taken in the Potter Creek Cave. This species is the common Squaw-fish of the Sacramento. See *op. cit.,* p. 18.

Family ATHERINIDÆ.

40. *Merriamella doryssa* Jordan, new genus and species.

Head, 3½ in length; depth, 6; D., I, I, 8; A., I, 7; C., 12 to 14; P., 11 or 12; vertebræ, 15 + 18 = 33.

Body moderately elongate, formed as in *Atherina;* the head larger and more pointed; mouth rather oblique, the lower jaw prominent, the maxillary apparently extending beyond front of eye; no signs of teeth; eye large, the orbit about three in head; opercles apparently unarmed, the opercle convex and striated; orbital region elevated, the profile depressed over the snout; branchiostegals slender, about six in number; pectoral fin inserted high, fan-shaped, the form apparently symmetrical, its length 2⅗ in head; no distinct traces of ventral fins on any of the four specimens.

First dorsal composed of a single moderate curved spine, sharply defined in all examples, inserted behind middle of length of pectoral at a distance from gill opening equal to two-thirds of head; length of dorsal spine about five in head. Soft dorsal en-

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tirely similar to anal, inserted a little in front of the latter, the anterior rays in both elevated, the height of the longest ray three in head, the base of the fin two, three in head. Caudal moder-

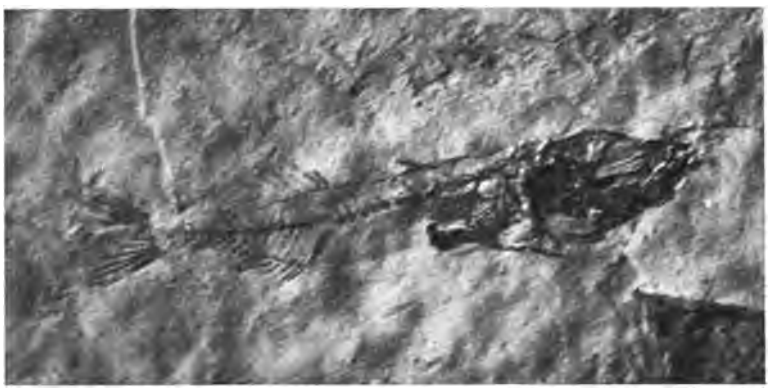

Fig. 25. *Merriamella doryssa* Jordan. Truckee River. Tertiary. Type specimen.

Fig. 26. *Merriamella doryssa* Jordan. Truckee River. Tertiary.

ately forked; bones slender, mostly very fine. There is no trace of scales in any specimen.

This species is known to us from four specimens, one and one-half to four inches long, found in the white marl in a cutting for

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the Truckee River Canal in Nevada. The rock, according to Professor Merriam, is probably of Miocene Age. This is a fresh-water deposit.

Two of the specimens, one of them the type described above, are much more slender in apparent form than the others, a difference which may indicate difference of species; the depth must have been at least six and one-half times in the length to base of caudal. In two others of equal length the body seems much deeper. In one the depth is about five times in length; in the other about four and one-half, but this last shows evidence of distortion. The technical characters so far as they can be made out seem to be the same in all, and we treat them provisionally as one species, which is probably the case.

In all the specimens the curved hook-like dorsal spine is very distinct, but in one of them it seems to be preceded by three other spines much more slender and shadowy. These possibly do not really belong to the same specimen, as in the other three the spine is very distinct and stands alone. If these are really additional spines, the generic diagnosis must be adjusted accordingly.

We propose for this fish the name *Merriamella doryssa.* If the genus is placed among the *Atherinidæ*, it will differ by its differentiated dorsal spine, which either stands alone or is preceded by three slenderer ones. It suggests also the genus *Hypoptychus,* a Siberian type of *Ammodytidæ. Hypoptychus* has no trace of the first dorsal. The genus *Merriamella* has also much in common with the extinct family of *Cobitopsidæ,* of the European Oligocene. But *Cobitopsis,* like *Hypoptychus,* has no first dorsal fin, and its ventral fins are present and abdominal.

Family SCOMBRIDÆ.

41. *Scombroid* fish.

Professor Agassiz records fragments of unidentifiable bones of mackerels from Ocoya Creek. We have also fragments from a vertebral column of some mackerel-like fish from Brown's Cañon, near Santa Monica. The vertebræ are strong, and well developed, the caudal peduncle slender and the tail well forked.

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Family SCORPÆNIDÆ.

Genus SEBASTODES Gill.

42. *Sebastodes rosæ* Eigenmann (Zoe, I, p. 16, 1890).

Preopercle of a fish about a foot long. Three lower preopercular spines subequal and equally spaced, all directed downward and backward. Preopercle much heavier than in *Sebastodes rosaceus,* the nearest living species. Three pits leading into mucous canals, decreasing in size backward on anterior half of first spine. A large pit between first and second preopercular spine, another between second and third, and two smaller ones on anterior half of second spine. (Eigenmann.)

Tertiary rocks at Port Harford, San Luis Obispo County.

Family LUVARIDÆ.

43. *Luvarus* species (?).

In the Los Angeles High School is a specimen of a large fossil fish, thirty-four inches in length, so poorly preserved that only the general form and the robust vertebræ are shown.

It is apparently a scombroid fish, that is, one belonging to some mackerel-like family. The genus *Luvarus,* of which a species, *Luvarus imperialis* Rafinesque, occurs on the coast of California, is suggested by the character of the vertebræ. The specimen might, however, belong to any one of a dozen genera living or extinct.

The specimen was found by Mr. J. Z. Gilbert, teacher of Zoology in the Los Angeles High School, and I am indebted to him for the accompanying photograph. Mr. Gilbert states that the specimen was found on the "Third Sea Beach," at about 2,000 feet from the lighthouse on Point Firmin, southwest of San Pedro. There occur five moon-shaped sea beaches from the lighthouse to the foot of the breakwater. The specimen was from a rock, not *in situ* but near a ledge of similar structure and appearance. The matrix is of a hard volcanic material overlying readily cleavable sandstone. The specimen represents probably only about one-half of the length of the animal when living. There are twenty vertebræ plainly visible, each measuring one and one-

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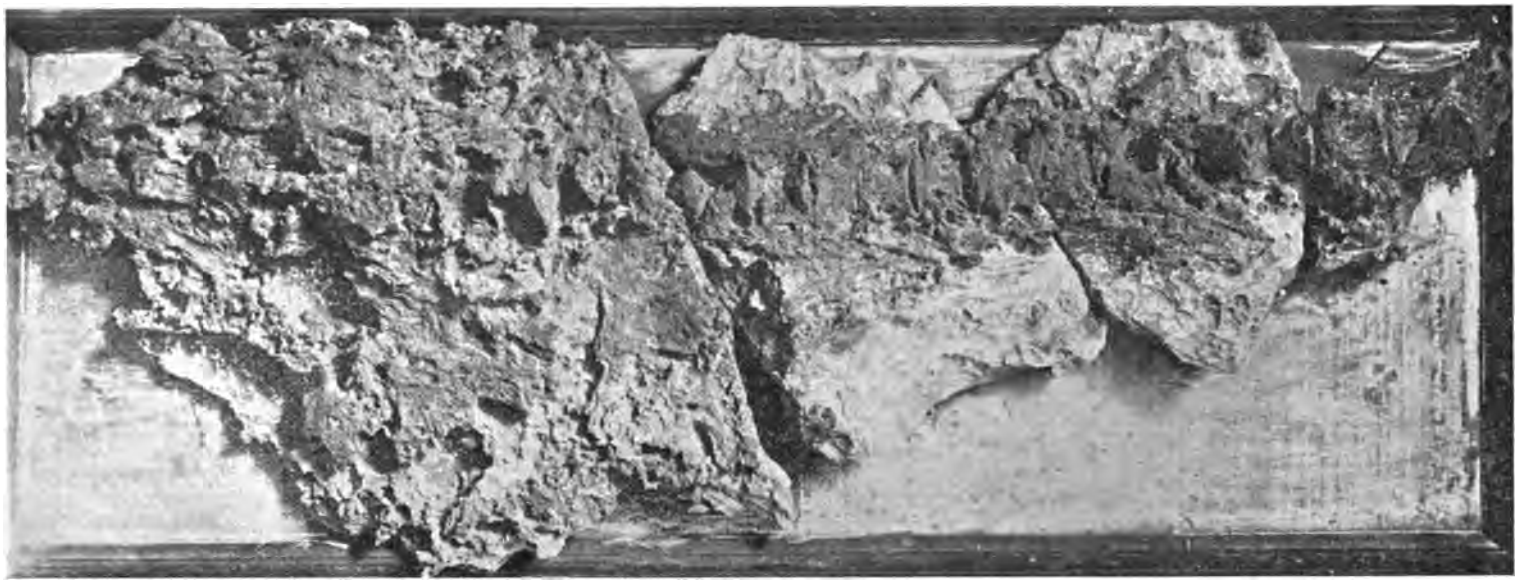

Luvarus sp. San Pedro, California.

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half inches in diameter and two and one-half inches in length. The vertebræ decrease only slightly in length backward. There were probably as many as forty in all.

RECAPITULATION.

By the geological horizons, these species may be classified as follows:

QUATERNARY.

Carcharodon riversi Jordan.
Carcharodon arnoldi Jordan.
Acipenser medirostris Agassiz?
Mylopharodon conocephalus (Baird and Girard).
Ptychochelius grandis (Ayres).
Urolophus halleri Cooper?

PLIOCENE.

Dalatias occidentalis (Agassiz).
Galeus (*zyopterus* Jordan and Gilbert)?
Carcharodon riversi Jordan.
Isurus tumulus (Agassiz).

MIOCENE.

Heptranchias andersoni Jordan.
(*Echinorhinus blakei* Agassiz.)
Dalatias occidentalis Agassiz.
Galeocerdo productus Agassiz.
Carcharias antiquus (Agassiz).
Carcharias sp.
Hemipristis heteropleurus Agassiz.
Lamna clavata Agassiz.
(*Lamna ornata* Agassiz.)
Isurus planus (Agassiz).
Isurus smithii Jordan.
Isurus tumulus (Agassiz).
Carcharodon arnoldi Jordan.
Carcharodon branneri Jordan.
(*Carcharodon rectus* Agassiz.)
Chiloscyllium species?
Aëtobatis species.
Etringus scintillans Jordan.
Etringus species?
Clupeoid fish A.
Clupeoid fish B.
Clupeoid fish C.
Pterothrissoid fish.
Rogenio solitudinis Jordan.

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Rogenio bowersi Jordan.
Merriamella doryssa Jordan.
Scombroid fish.
Sebastodes rosæ Eigenmann.

CRETACEOUS (Chico formation).

Hemipristis chiconis Jordan.
Lamna species?
Isurus desorii (Agassiz)?
Phareodus species?

TRIASSIC.

Hybodus shastenis Wemple.
Acrodus wempliæ Jordan.
Holoptychus species.
Xenesthes velox Jordan.

SUPPLEMENTARY NOTES ON AMERICAN FOSSIL FISHES.

Family CLUPEIDÆ.

Genus KNIGHTIA Jordan (new genus).

Knightia eocæna Jordan (*Clupea humilis* Leidy), new specific name.

In his monumental work on the Tertiary Vertebrata, 1884, p. 74, Professor Cope calls attention to the fact that the genus *Diplomystus* of Cope is composed of two sections. In the typical section *Diplomystus* (*dentatus*) the dorsal scutes are transverse with pectinate borders, a median tooth being especially prominent. In the second section, the scutes are not wider than long, and there is but a single median tooth, at the end of a median longitudinal carina.

These two sections differ in other regards, and the second may well be held to constitute a distinct genus, to which I suggest the name of *Knightia*, in honor of the late Wilbur Clinton Knight, of the University of Wyoming, an indefatigable student of the palæontology of the Rocky Mountains.

The type of *Knightia* is *Clupea humilis* Leidy = *Clupea pusilla* Cope. As the name *humilis* is preoccupied in *Clupea* by *Clupea humilis* von Meyer, and the name *pusilla* by *Clupea pusilla* Mitchill, the species is left without a distinctive title and may stand as *Knightia eocæna* Jordan. The species is not very

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different from *Knightia alta* (Leidy), also found in the Green River shales. *K. alta* has the body deeper than in *K. eocæna.*

In *Knightia* the body is more elongate than in *Diplomystus,* the ventral outline and the post-nuchal region not especially prominent; the lower jaw is less prominent and the cleft of the mouth less oblique; the scales are much larger, about thirty-five (over sixty in *Diplomystus*), and the anal fin and the corresponding part of the vertebral column is much shorter. In *Diplomystus* the anal fin has thirty to forty rays, the caudal region having about twenty-five vertebræ. In *Knightia* there are about fourteen anal rays, corresponding to about fifteen vertebræ. There are in all about forty-one vertebræ in *Diplomystus* and thirty-five in *Knightia.* According to Cope, the anterior neural spines in *Knightia* are without antero-posterior laminar expansion.

Knightia eocæna is perhaps the most abundant fish in the Eocene shales of Green River, in which locality *Diplomystus dentatus* and related species of primitive herrings abound.

The name *Histiurus Costa* (1850), which is perhaps a synonym of *Knightia,* has been earlier used by Agassiz, as an emendation of *Istiurus* Cuvier, a genus of reptiles.

Very recently, Dr. Louis Dollo (Res. Voyage Belgica, 1904, p. 159) has proposed the new generic name *Copeichthys* Dollo, as a substitute for the name *Diplomystus* of Cope, which Dollo regards as preoccupied by the name *Diplomystes* of Bleeker, a name which Dr. Günther has altered, unnecessarily I think, to *Diplomystax.* In the judgment of the present writer, *Diplomystes* and *Diplomystus* are different words, however similar in spelling and in etymology, and the name *Copeichthys* is not admissible.

Family SALMONIDÆ.

Genus ONCORHYNCHUS Suckley.

Oncorhynchus [? *tschawytscha* (Walbaum)].

In ferrugineous shales of Post-pliocene Age, from Fossil Lake, Oregon, are found numerous fragments of the jaws, teeth, and vertebræ of a species of salmon which must have reached a considerable size. Nothing in these fragments distinguishes the spe-

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Fig. 27. *Oncorhynchus tschawytscha?* (Jaws and teeth.) Quaternary? Near Fossil Lake, Oregon.

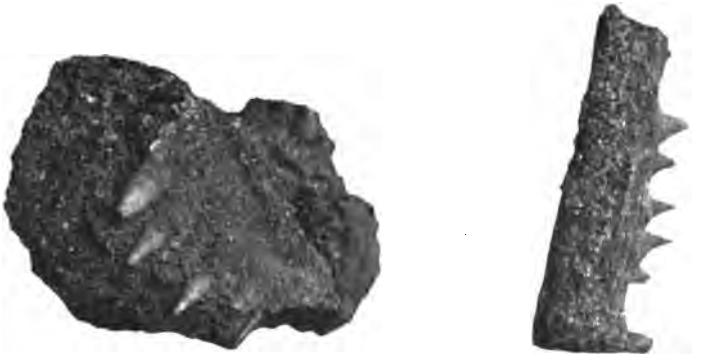

Fig. 28. *Oncorhynchus tschawytscha?*

Fig. 29. *Oncorhynchus tschawytscha?* (Jaw with teeth.) Quaternary? Near Fossil Lake, Oregon.

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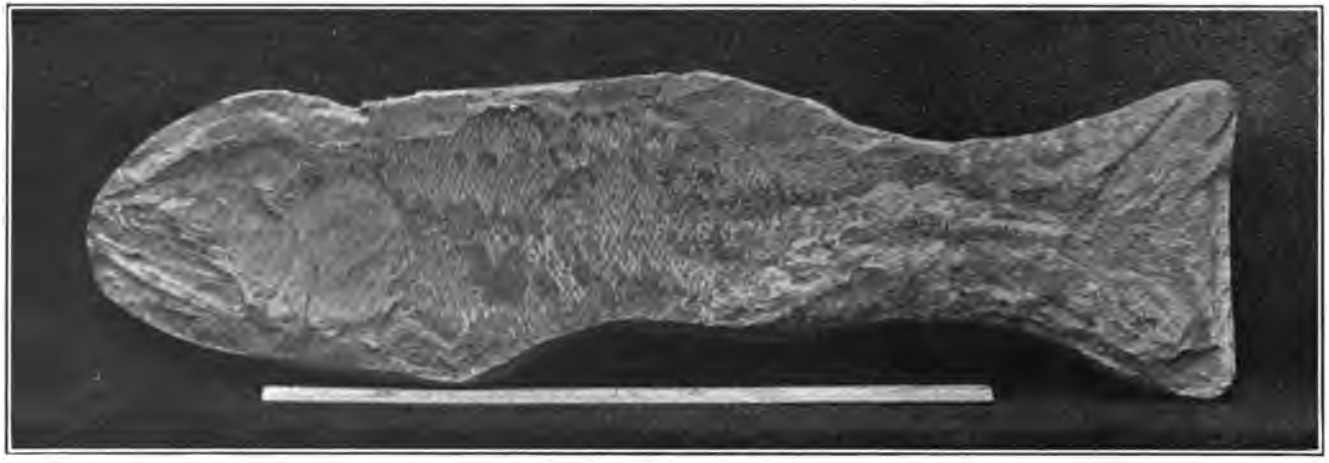

Calamopleurus cylindricus (Agassiz). Barra do Jardim Ceará, Brazil.

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cies from the King Salmon or Chinook Salmon, which now runs up from the sea to spawn in the same region. We may therefore provisionally record it as *Oncorhynchus tschawytscha.* These jaws seem to represent the distortion peculiar to the breeding season. It is interesting to know that the anadromous habits of these fishes are of such long standing.

Fig. 30. *Oncorhynchus tschawytscha* (Walbaum). (Ramus of lower jaw.) Quaternary? Near Fossil Lake, Oregon.

Similar remains of fragments of jaws, teeth, and vertebræ were obtained from diatomaceous deposits on Lost River, Oregon, and sent to the University of California by Mr. Selden Ogle of Klamath Falls.

Family ELOPIDÆ.

Genus CALAMOPLEURUS Agassiz.

Calamopleurus cylindricus (Agassiz).

A specimen of this species was found in a long club-shaped concretion about a foot and a half in length (48 cent.) from the interior of the state of Ceará in Brazil. This was presented to Dr. John Branner by Dr. Paulo Pessoa of Rio de Janeiro, and is now in the Museum of Stanford University. On breaking the concretion lengthwise, a fine specimen of this species was disclosed. We here present the photograph of this specimen.

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Family CHARACINIDÆ.

Genus EOBRYCON Jordan, new genus.

Eobrycon avus (Woodward).

(*Tetragonopterus avus* Woodward, Rev. Mus. Paulista, III, p. 66, 1898, Taubaté.)

Of this species Dr. Branner has received numerous fine specimens through Dr. Paulo Pessoa of Rio de Janeiro, from the Tertiary Lignite of Taubaté, in the Province of Saõ Paulo, Brazil.

Fig. 31. *Eobrycon avus* (Woodward). Lignite of Taubati.

While this species is doubtless a *Characin*, and allied to *Tetragonopterus*, its oblong and robust form separates it from that genus, in which the body is very deep and laterally compressed. I suggest the generic name of *Eobrycon*.

Family CATOSTOMIDÆ.

Genus CHASMISTES Jordan and Gilbert.

From a lake deposit in Oregon, near Fossil Lake, and probably of Quaternary Age, Dr. Merriam has obtained a large number of crania of suckers, some of them of large size, probably belonging to the genus *Chasmistes* now living in the same region.

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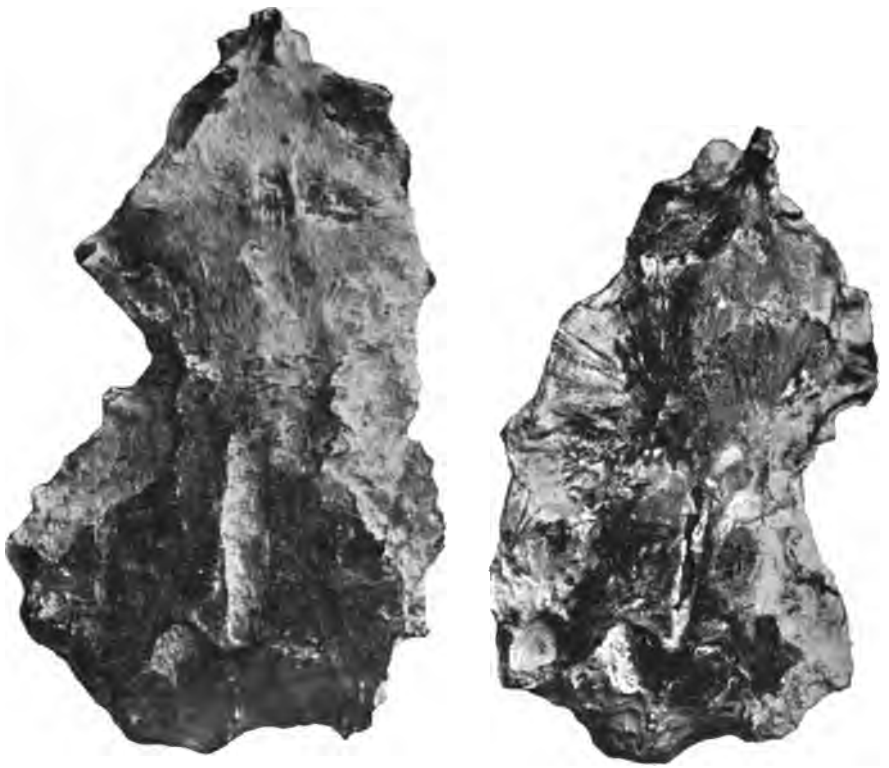
Four of these are in very good condition, and these have been studied by Mr. Edwin Chapin Starks. The following paragraphs are taken from Mr. Starks' manuscripts referring to these fishes.

Chasmistes oregonus Starks, new species.

Of the four crania especially examined, the first (number 1 of the appended table) appears to be the species referred by Cope (Proc. Acad. Nat. Sci. Phil. 1883, p. 151) to the living spe-



A B

Fig. 32. A, *Chasmistes* sp. Quaternary, Fossil Lake, Oregon. B, *Chasmistes oregonus* Starks. Quaternary, Fossil Lake, Oregon. Type specimen.

cies *Catostomus labiatus* Ayres, from Klamath Lake (properly *Catostomus snyderi* Gilbert, the representative in Klamath Lake of *C. occidentalis*). The true *Catostomus labiatus* is a different species, from Sacramento River, earlier called *Catostomus occi-*

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dentalis by Agassiz. Cope states that the ethmoid of his fossil specimens is half as long as wide. If that be so, they cannot be referred to *Catostomus snyderi,* as in that species the length of the ethmoid is from three-fourths to four-fifths of the width. Possibly he compared his specimens with skulls of *Chasmistes* (two species of which are found in Klamath Lake), in which the length of the ethmoid is from two-fifths to three-fifths of the width. In our cranium number one the anterior part is conspicuously convex transversely as well as in profile. There is no frontal keel in front of the fontanelle, and the fontanelle is rather narrow as compared with other specimens. A sharp supratemporal keel is developed laterally and overhangs the temporal fossa. In *Catostomus snyderi* the surface of the frontal rises from the temporal fossa over a smooth, rounded, supratemporal ridge to the superior surface, and the ridge is not developed laterally as an overhanging crest. This may be named *Chasmistes oregonus,* new species.

Cranium number two differs from number one in being flatter across the ethmoid and anterior frontal regions, in having a wider frontanelle and a frontal keel developed. In the two latter characters it resembles number three, though in general characters it is evidently closer to number one. This species we leave unnamed for the present.

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Chasmistes batrachops (Cope).

Cranium number three has a greater interorbital width and a greater width across the pterotics and apices of the epiotics. The region behind the supraoccipital which descends to the basioccipital is wider and flatter. In general width, except in width of ethmoid, this cranium approaches *Catostomus* or *Chasmistes batrachops* Cope, with which it may be provisionally identified.

Fig. 33. *Chasmistes batrachops* (Cope). Quaternary, Fossil Lake, Oregon.

Our remaining fossil, *Chasmistes* or *Catostomus,* has only the opercular region and the anterior part of the cranium remaining. It is evidently close to numbers one and two. It is too fragmentary to admit of any measurements being given to advantage.

In the appended table the measurements of *Catostomus occidentalis* and *Chasmistes stomias* show that all of these fossils are nearer to the latter, though differing from it in many respects. This does not necessarily mean that they belong to the genus *Chasmistes,* although that is probable.

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MEASUREMENTS OF CRANIA.

In the following table in the first column under each specimen are measurements in millimeters; in the second are hundredths of the length from the posterior end of the epiotic to the tip of the ethmoid spine. Measurements under numbers 1 to 3 are of fossil crania in our collection; under number 4 are those published by Cope of *"Catostomus" batrachops,* and the hundredths measurements are reduced from them; under number 5 are measurements of the existing species *Chasmistes stomias* Gilbert; and under number 6 of the existing species *Catostomus occidentalis* Ayres.

	Chasmistes oregonus.		*Chasmistes*		*Chasmistes batrachops?*		*Catostamus batrachops.*		*Chasmistes stomias.*		*Catostamus occidentalis.*	
Specimen number	1		2		3		4		5		6	
Measurement	mm.	100ths.	mm.	100ths.	mm.	100ths.	mm.	100ths.	mm.	100ths.	mm.	100ths.
Length from posterior end of epiotic to tip of ethmoid spine ...	83		86		*92		84		63		49	
Length of ethmoid (median) without spine..	19	24	19	28	20	22	18	22		29		23
Length of parietal (median)	16	20	17	20	17	19	15	18		20		18
Length of frontal	32	39	35	41	35	38	32	38		41		38
Interorbital width	45	55	*	*	55	60	56	66		65		48
Least width between interorbital frontal ridges	15	18	17	20	17	19				16		23
Greatest width across pterotics *52		*63	51	60	64	70	*62	*73		60		57
Width between apices of epiotics	26	32	26	31	33	36	32	38		35		24
Width of ethmoid	32	39	34	40	36	40	42	49		46		31

* Approximately; so broken that exact measurement cannot be given.

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UNIVERSITY OF CALIFORNIA PUBLICATIONS
BULLETIN OF THE DEPARTMENT OF
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Vol. 5, No. 8, pp. 145-148 ANDREW C. LAWSON, Editor

FISH REMAINS FROM THE MARINE LOWER TRIASSIC OF ASPEN RIDGE, IDAHO

BY
MALCOLM GODDARD.

The fragmentary fish remains described in the following paper were obtained on a paleontological expedition visiting southern Idaho during the summer of 1903 for the purpose of studying the Lower Triassic outcrops at Aspen Ridge, about ten miles east of Soda Springs.

The material is all very fragmentary, consisting of disarticulated bones, occurring in thin slabs of shaly limestone. The rock abounds in ammonites and in some cases is practically composed of them. The forms present, of which the characteristic one is *Meekoceras,* point to the horizon as Lower Triassic. Professor James Perrin Smith of the Leland Stanford Junior University, who has made a special investigation of the invertebrate fauna of this horizon, places it in the Lower Triassic, below the beds of Paris Cañon from which H. M. Evans has recently described a new cestraciont spine.[1] The deposit in which the bones occur is of marine origin, as shown by the abundance of cephalopods and other marine molluscs, and in this respect differs from the deposit in which the type specimen of *Megalichthys* was found, which is a fresh-water limestone. The remains seem, however, closely allied to those of fresh-water formations.

The material collected at Aspen Ridge contains 81 specimens, comprising fragments of jaws, teeth, scales, supposed opercular bones and a number of bones which are indeterminable. Most

[1] Bull. Geol. Dept. Univ. of Cal., Vol. 3, No. 18, p. 397, pl. 47.

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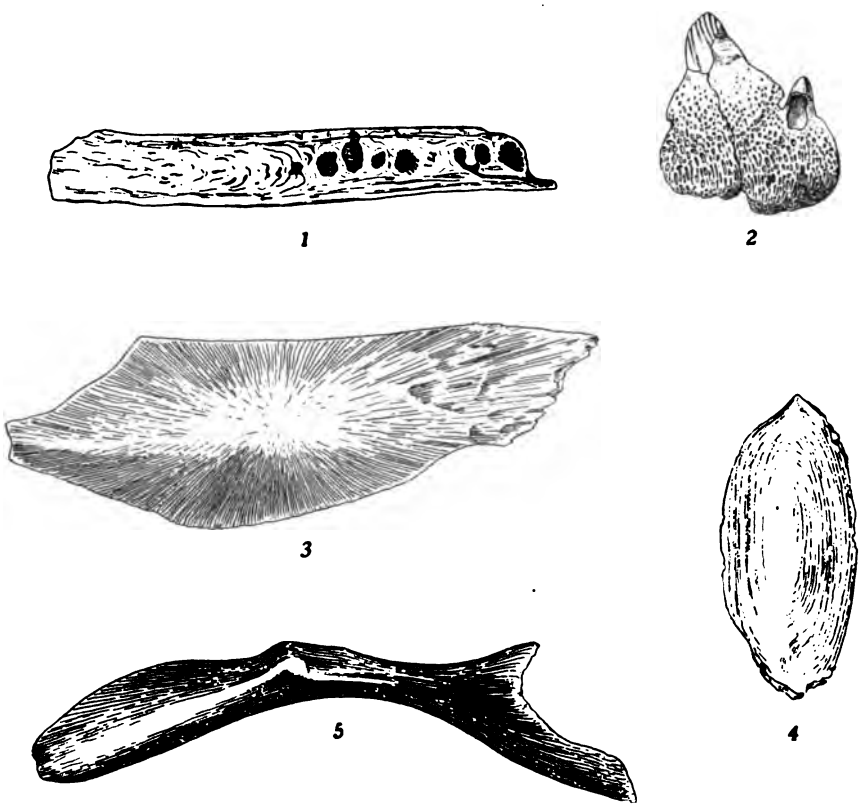
of the specimens described in this paper resemble the crossopterygian ganoids and may be referred to the family, Megalichthyidae,[2] on account of the tooth structure, the variation in size of the teeth, and the structure of the dermal plates.

The teeth which have been obtained are conical, with a pulp cavity of which the walls are vertically folded towards the base.[3]



Figs. 1 and 2 natural size; figs. 3, 4, and 5 one-half natural size.

They are firmly set in the bone, are close together, and all were apparently functional at the same time. There is a great variation in size which is a character common with *Megalichthys hibberti* as described by Dr. Hibbert.[4] The basal portions of the

[2] Hay, O. P., Catlg. of Fos. Vert. North Amer., p. 359.
[3] Woodward, A. S., Catlg. Fos. Fish. Brit. Mus. Pl. II.
[4] Trans. Roy. Soc. Edinb., XIII, pp. 169-282. Pl. V-XIII.

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teeth are covered with coarse longitudinal folds, another character common with *Megalichthys.*

The punctate character of the large plate may be considered as pointing rather toward the Osteolepidae than to *Megalichthys.*

The following specimens show characters which are considered worthy of notice.

Specimen No. 10823.—This is a fragment of jaw (fig. 1) 65 mm. in length and 12 mm. in width containing eight distinguishable teeth, one of which shows a length of 5 mm. With one exception, the teeth are shown in cross-section only. They average 2.5 mm. by 3.5 mm. in diameter and show distinctly a deep plication at the base, the folds of dentine extending into the pulp cavity almost to the center. The external part of the tooth shows deep longitudinal folds for about one-third of the distance from the base to the apex. The teeth are set firmly in the bone.

This specimen very much resembles the members of the Rhizodontidae, as described by Woodward,[5] in their conical form and vertical folding of the walls of the pulp cavity towards the base. There is also a resemblance to the Osteolepidae[6] which have "teeth conical, with a pulp cavity, of which the walls are not folded except quite at the base."

Specimen No. 9991.—Figure 2 probably represents a dentary bone bearing four teeth of different sizes, three of which are almost in direct alignment; the other, a smaller one, lies at the side. No. 1, the smallest, has a length of 7 mm., diameter at the base 3.8 mm. It has a conical form and a large pulp cavity reaching almost to the apex, and well down into the base, which is set firmly in the bone. No. 2 is the base of a conical tooth with external longitudinal folds. No. 3 is a long tapering tooth with coarse longitudinal folds extending almost to the apex and having a length of 12 mm. and a diameter at the base of 5.8 mm. No. 4 is a large tooth having an approximate length of 14 mm. and a diameter at the base of 8 mm., with very large coarse longitudinal folds from base to apex.

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[5] Woodward, A. S., Catlg. Fos. Fish. Brit. Mus., Vol. II, p. 341.

[6] *Ibid.*, p. 367.

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Specimen No. 9988.—Figure 3 represents a plate with a length of 164 mm. The greatest width is 50 mm. The plate shows fine lines radiating from a common center to the periphery, the highest point being at the center. The surface is covered with small pits or dots. It resembles very much the frontal plate of *Onychodus sigmoides* Newb, as figured by Dr. Newberry,[7] in having lines radiating to all parts from a common center, except that the radiating ridges are not so pronounced, and in that the specimen is relatively long for its width. It resembles *Megalichthys hibberti* in having the surface covered with fine pits or dots.[8]

Specimen No. 9900.—A long slender bone (fig. 5) constricted on each side of the middle, which is swollen on one edge resembling a point of articulation. The ends flare out on one side to a thin convex fan, the planes of the expanded portions being twisted at an angle of about 70°. Length about 160 mm., diameter at narrowest point 9 mm., diameter at swollen portion 13.5 mm.

Specimen No. 9987.—Figure 4 represents the impression of the inside of a cycloidal scale showing oval outlines parallel to the periphery. Length 76 mm., width 35 mm. The impression resembles the inner aspect of a scale of *Rhizodus ornatus* Trq. figured by Woodward.[9] If this specimen belongs to the same form as the folded teeth, the greater affinity is with the Megalichthyidae rather than with the Osteolepidae, as the scales are of cycloidal shape.

[7] Newberry, J. S., U. S. Geol. Surv. Mon., Vol. 16, pl. 37.
[8] Trans. Roy. Soc. Edinb., Vol. XIII, p. 194.
[9] Woodward, A. S., Catlg. of Fos. Fish. Brit. Mus., Vol. II, Pl. XII, fig. 9.

Issued May 18, 1907.

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UNIVERSITY OF CALIFORNIA PUBLICATIONS
BULLETIN OF THE DEPARTMENT OF
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BENITOITE, A NEW CALIFORNIA GEM MINERAL.

BY
GEORGE DAVIS LOUDERBACK,
WITH CHEMICAL ANALYSIS BY
WALTER C. BLASDALE.

The mineral which is the subject of this note was discovered early in this year by Mr. Hawkins and T. Edwin Sanders, who were prospecting in the southern part of the Mt. Diablo range, near the San Benito-Fresno County line, about latitude 36° 20′. It was first brought to the writer's attention by Shreve & Company, who had purchased one of the cut stones from a lapidary and who were later offered some of the rough material as sapphire. They soon determined that it was not sapphire but were unable to place it, and so sought the aid of the University. Sufficient material for the chemical analysis and for the crystallographic and other determinations was kindly supplied by Mr. Hal Sanders of San Francisco, a brother of one of the original discoverers. The writer is also indebted to Professor O'Neill for the privileges of the chemical laboratory and for many courtesies.

As the progress of the investigation has shown that it is a new mineral species, it has been called benitoite, as it occurs near the head waters of the San Benito River in San Benito County.

The most striking characteristic of the mineral is its blue color, and selected crystals cut in the right direction produce a

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beautiful gem stone that rivals the sapphire in color and excels it in brilliancy. The color, however, although fairly characteristic, is not an essential property, for very commonly parts of a crystal are colorless, while occasionally perfectly colorless small crystals are found. The color also varies in intensity in different crystals or in parts of the same crystal. When pale it is a rather pure blue. When more intense it assumes a violet tint. In addition to this variation in color in different parts of crystals, there is a difference at any one point, depending on the direction in which the light passes. In other words, the mineral is strongly dichroic, the ordinary ray being colorless, the extraordinary, blue. A section cut parallel to the basal plane is practically colorless, while sections parallel to the principal axis show the deepest color. To get the finest effect, therefore, gems should be cut with the table parallel to the principal axis, and this is in contrast to the sapphire, which shows its color best when cut perpendicularly thereto. If such a section, cut so as to give the strongest color effects, be examined with a dichroscope, the contrast between the images is most striking. The image of the extraordinary ray being freed from the colorless image of the ordinary ray, presents a remarkable intensity of color, very much deeper, of course, than can be seen by looking at the mineral in any direction with the unaided eye. In the lighter parts this color of the extraordinary ray is a slightly greenish blue inclining to indigo as it becomes darker, and is very similar to one of the axial colors shown by some cordierites; but in the more highly colored or thicker parts it is an intense purplish blue.

The color is not affected by heat up to the melting point of the mineral. Fragments heated to a rather bright red and maintained at that heat, just short of fusion, for five minutes showed no change whatever on cooling.

Benitoite occurs generally in individual simple crystals scattered through the matrix and varying from a few millimeters to about two centimeters across. The matrix being translucent white, the blue transparent crystals stand out prominently and often show crystal faces.

It crystallizes in the hexagonal system, trigonal division. The observed forms are the basal plane, the plus and minus

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trigonal pyramid and the corresponding trigonal prisms. The normal angle between the basal plane and the pyramid is about 40° 14′. If the pyramid be taken as a unit pyramid of the first order, this would yield an axial ratio of .7327, if of the second order, .8460.

The most common habit is pyramidal, one pyramid being the chief form, the other occurring as a small but regular and brilliant truncation. One or both prisms may be present as narrow truncations and also a small triangular basal plane.

Occasionally the base is developed into a broad plane, the crystals then having a more nearly tabular habit. The outline of the base may then be hexagonal but the edges corresponding to one pyramid will be considerably longer than the others.

Only one crystal was found where the two pyramids were nearly equally developed. The development of the faces at one end of the principal axis always corresponds so well with those at the other, that it gives the impression that the horizontal plane of symmetry is present. No tendency towards a prismatic habit was observed. The angles between two adjoining pyramid faces at one end of axis is 68° 1′. There is an imperfect pyramidal cleavage. The fracture is conchoidal to subconchoidal. The hardness is 6¼-6½; distinctly above orthoclase and labradorite and below chrysolite and quartz; density, 3.64-3.65.

The refractive index is quite high, which adds greatly to the beauty of the cut stone. For the ordinary ray it is about 1.77 (sodium light), for the extraordinary, about 1.80. The double refraction is therefore very strong and the mineral optically positive. Basal sections show a perfect uniaxial cross which gives a distinct positive reaction with the mica plate. The pleochroism has already been described and evidently the absorption is $e > o$. Some difficulty was experienced in getting a value for ϵ, as sodium light is strongly absorbed even in light colored specimens a couple of millimeters thick.

The mineral fuses quietly to a transparent glass at about 3. It is practically insoluble in hydrochloric acid, but it is quite easily attacked by hydrofluoric acid, and dissolves readily in fused sodium carbonate.

The mineral has proved to be of considerable interest from

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the standpoint of its chemical composition. Professor Blasdale, who kindly undertook the chemical analysis, reports:

	A.	B.	Average.	Mol. Ratios.
SiO_2	43.56	43.79	43.68	.723
TiO_2	20.18	20.00	20.09	.250
BaO	36.34	36.31	36.33	.237
	100.08	100.10		

The suggested formula is $BaTiSi_3O_9$, which yields the following calculated values:

SiO_2	43.71
TiO_2	19.32
BaO	36.97
	100.00

Professor Blasdale also reports that the mineral is easily decomposed by hydrofluoric acid, but only slowly attacked by molten potassium pyrosulphate.

Benitoite is then a very acid titano-silicate of barium, and stands in a class by itself, both as regards acid silicates and titano-silicates. The possibility of the titanium acting as a base was considered, but the summation of the analyses and the fact that the crystals are often perfectly colorless seem to point definitely to the above interpretation. The blue color of much of the material may be due to a small amount of titanium in the sesquioxide condition.

Associated with benitoite is a black or brownish black prismatic mineral that also appears to be new. Its most striking characteristic is a very perfect prismatic cleavage of 80° 10′. Its hardness is between 5 and 6 and it melts easily, at about 1.5, giving a sodium flame and becoming a lustrous black enamel bead. It appears to be monoclinic, is biaxial, and gives an extinction angle of about 10 degrees on the cleavage face. Its cross sections are six-sided, the four cleavage traces being truncated by a lateral pinacoid. In thick pieces it is opaque, but in moderately thin ones it is a deep rich red, which changes to a brownish or ocreous yellow as the thickness decreases. Pleochroism is prominent. On a cleavage plate the ray vibrating near the prism

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axis is yellowish brown or ocreous yellow to reddish brown, the one perpendicular to this light yellow, absorption $c' > a'$ in which c' lies nearest the prism axis. The refractive index is high—at least greater than that of monobromnaphthalene, 1.654.

The name carlosite is suggested for this mineral, from the nearby San Carlos peak, one of the highest points of that part of the range.

Benitoite and carlosite occur as individual disseminated crystals in narrow veins in a basic igneous rock or in a schist which has been considerably altered by the solutions that formed the veins. The benitoite is apparently restricted to the veins, the carlosite also occurring in the neighboring parts of the wall rock. The chief gangue of the veins is a soda rich zeolite. The properties of carlosite and the nature of the gangue were determined on small and unsatisfactory quantities, as the collectors were interested in the supposed sapphires and not in its matrix. The writer has recently been able to collect specimens of the matrix and crystals of carlosite and expects shortly to make a more extensive report on the properties of benitoite and carlosite, their paragenesis, etc.

Issued July 30, 1907.

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NOTES ON QUATERNARY FELIDAE FROM CALIFORNIA.

BY

JOHN F. BOVARD.

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INTRODUCTION.

At the present time the only known fossil Felidae in California are from Quaternary deposits, with the possible exception of one species, *Felis imperialis* Leidy, of which the occurrence is somewhat uncertain. Feline remains are thus far known from three classes of deposits, the asphaltum beds of southern California, the alluvial beds of the central part of the state, and the cave deposits in Shasta County.

The asphaltum beds in which remains of felines have been found are located nine miles west of Los Angeles. The bones are

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scattered over a large area, in many places showing on the surface. The thickness of the bone layers is not constant; in some places the bones are considerably scattered and in other places there are large quantities in small areas. The bones are for the most part well preserved, but in many cases they have been infiltrated with asphaltum and are exceedingly brittle.

In a recent article Professor J. C. Merriam[1] has stated that there are associated with these cats in these asphalt deposits the remains of other mammals such as *Elephas, Equus, Bison,* a mylodont, a camel, and also those of large birds. Such animals would on being mired down in the soft asphaltum become the prey of the carnivores, and the latter in turn would be caught in the gummy bitumen.

A specimen which must also be classed with the asphaltum material is the type of *Machaerodus ischyrus* from Asphalto, Kern County. The type, a mandible, was found in association with asphalt deposits.

Only one species, *Felis imperialis* Leidy, is known from the alluvial deposits of California. This was found in Livermore Valley a number of years ago and was sold to Wabash College, Indiana. The exact locality has not been recorded, so that there is a possibility that this form is Pliocene. If Pliocene, it is the only Californian feline known that is older than the Qaternary.

To the material already mentioned must be added that from the caves of northern California. Numerous more or less fragmentary specimens have been found by Mr. Furlong and Dr. Sinclair in the deposits of Samwel Cave and Potter Creek Cave on the McCloud River. The best known of the cave cats is *Felis hippolestes* Merriam, C. H., found in the Samwel Cave by Mr. E. L. Furlong.[2] Several mandibles with the dentition were found in the Potter Creek Cave.[3] These all correspond quite closely to the cats now living in California.

The author's studies on the Quaternary Felidae were carried on under the supervision of Professor J. C. Merriam, to whom I

[1] Science N. S., Vol. XXIV, No. 608, pp. 248-250.

[2] Am. Jour. Sci. N. S., Vol. XX, No. 497, pp. 53-55.

[3] Sinclair, W. J., Univ. Calif. Pub. Am. Arch. and Eth., Vol. 2, No. 1, p. 17.

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wish to express my sincerest appreciation for his kindly suggestions and for the arrangement of the paper. Professor Merriam and Dr. C. Hart Merriam have compared the Potter Creek material with that of the U. S. National Museum, and I am indebted to them for the use of their notes. Through the kindness of Mr. W. W. Orcutt certain material from the asphalt deposits was loaned the University and has been useful in making comparisons.

SMILODON CALIFORNICUS, n. sp.

Pl. 13, figs. 1-4.

Specific Characters.—P_3 absent, M_1 with an anterior basal cusp, inferior diastema short, symphysis deep and extending below the inferior border of the horizontal ramus of the mandible.

Material.—The material available consists of an almost complete skull, and considerable fragments of several others. The mandible is represented by the left rami of two individuals, and by the fragments of three others. There is also the posterior half of the left ramus of a kitten. The limb bones are fragmentary. They consist of the distal end of the humerus, the proximal end of the tibia and numerous podial bones. Of the teeth we have the superior incisors, several sabers and the superior sectorial, also specimens representing the complete dentition of the lower jaw. A kitten jaw shows the milk molars, and the permanent sectorial just coming through.

Occurrence.—The type specimen is a mandible (No. $\overline{10210}$, Univ. of Cal. Col. Vert. Palae.) from the asphaltum beds nine miles west of Los Angeles, California.

Some of the material was found on a dump where excavations had been made to get out the asphaltum, but the larger part was found in place. Along with the cat bones were those of the horse, wolf, bison, camel, and ground-sloth. The deposits are of Quaternary age.

Mandible.—The lower jaw belongs distinctly to the *Smilodon* type. The horizontal ramus is rounded, smooth, and slender. The anterior surface is strongly concave, due to a wide ridge which extends forward and downward, and separates the anterior surface from the lateral surface. This ridge is continuous with a rudimentary flange which has an anteroposterior diameter of

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20 mm. and a height of 5 mm. The symphysis is very large and strong, the surface of contact being oval in shape and extending far down. The coronoid process is larger and broader than in *S. neogaeus,* and is more anterior in its position.

The angle of the jaw is small, and therefore does not interfere with the wide opening of the mouth. The two teeth P_4 and M_1 are situated about the middle of the mandible and directed backward obliquely at a considerable angle. The position of the teeth is important in the comparison with South American species.

The inferior diastema is short, and when we add to this the fact that P_3 is absent, it makes the diastema relatively shorter still. There is a single mental foramen.

In another specimen, No. 10412, the upward curvature of the jaw at the anterior end is quite marked. The coronoid elevation is small and located close to articular process. In other respects this jaw resembles the type specimen closely. In one half of the material the jaw is straight and the coronoid process is well forward. This includes the type specimen. The other half of the material shows the upward curvature of the jaw and posterior position of the coronoid process. These differences are possibly sexual or varietal.

Cranium.—A skull (No. 10948) which may belong to this species is about the same size as *Smilodon neogaeus* and *S. necator,* and conforms to the general form and shape of the skull in these South American forms. In this specimen the left zygomatic arch is missing and on the right side the post glenoid and mastoid processes are worn to a considerable extent, so that it is impossible to tell whether these processes were fused, as it is in the South American forms. The glenoid fossa is at about the level of the roof of the mouth, allowing great freedom to the lower jaw. The anterior border of the posterior nares is located 23 mm. behind the molars, a position quite a little posterior to that seen in *S. floridanus,* Leidy. The horizontal surfaces of palatines and maxillaries forming the roof of the mouth have well marked ridges running anteroposteriorly. Writing of the type specimen of *S. floridanus,*[4] Leidy says: "The hard palate

[4] Trans. Wagner Free Instit. Sci. Philad., Vol. 2, pp. 15, 1889.

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is less level than in the tiger and exhibits the same conspicuous depressions represented in Dr. Burmeister's figure of the same part in *M. neogaeus.*" In the California specimen it is evident that the palate is devoid of depressions such as are found in *S. neogaeus,* but on the other hand is marked by very prominent short ridges. The space included between the lateral ridges is not so rough. The posterior palatine canals are located just laterad of the lateral ridges at about the level of the anterior border of the superior sectorial.

The fore and aft space of the teeth is shorter than in *S. floridanus,* and the muzzle is shorter. The width is about the same at the canines, while the California specimen is slightly narrower at the sectorials.

Dentition.—The dental formula of the adult is $\frac{3}{3}$, $\frac{1}{1}$, $\frac{2}{1}$, $\frac{1}{1}$. In the collection the entire dentition is represented with the exception of M^1; of the milk dentition, the incisors and cheek teeth are present. The dentition shows a relatively high degree of specialization, indicating that *S. californicus* was among the most recent of the saber-tooth cats.

The superior incisors are large, gradually increasing in size from the inner to the outer teeth. Each bears at the base on the internal median surface a prominent basal tubercle.

The lower canines are stout and short and about twice the size of the external incisor. They have a single tubercle on the internal medial surface (pl. 13, fig. 3).

The superior canines are very long, but do not quite reach the proportions of those in *S. neogaeus* or *S. necator.* The average length is about 224 mm. Blainville's figure[5] of *S. neogaeus* shows that the enamel of the tooth does not cover the exposed portion entirely. Five sabers in our collection show that this was true for the Californian species also. The distal two-fifths of the saber is entirely covered with enamel, the middle fifth has only a narrow strip along the posterior edge, while the remaining two-fifths constitute the root proper. Both edges are sharply serrated. The inner or median surface is flatter than the outer, which is strongly convex.

[5] Osteographie des Mammifers Atlas 2, Pl. XX.

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P^3 is badly crushed, but presents no peculiarities as far as can be ascertained. The lower premolar, P_4, has two well developed posterior cusps behind the protoconid, but does not differ materially from the same tooth in *S. neogaeus* or *S. necator*. The superior sectorial presents the least variation from the type of sectorial for the typical *Smilodon*. It is somewhat smaller than in the South American species, but about the same size as in *S. floridanus*. The posterior lobe is long and stout, showing a tendency toward division into two parts. There is a well developed basal tubercle in front of the protostyle.

The inferior sectorial shows a decided specialization in the development of a distinctly separated basal cusp in front of the paraconid in two specimens (Nos. 10210 and 10258). The protoconid blade is considerably longer than the paraconid and shows a small heel clearly separated from its posterior border. On plate 13, figure 2, both heel and anterior basal tubercle are shown, though the anterior tubercle has been largely worn away. In the dimensions of M_1 there is some variation. A well worn molar is thicker but shorter than the tooth of a younger individual.

Relationships.—The resemblance of this form to *Smilodon floridanus* is very close. On comparison, the skulls show striking similarities in the general shape and size. Some of the differences are in the fore and aft space of the teeth, and therefore the length of the muzzle, that of the California specimen being somewhat shorter. The greatest variation is in the position of the posterior nares, its distance behind the molar series being 23 mm., while in *floridanus* it is slightly in advance of M^1. *S. floridanus* Leidy is the only skull of a North American saber-tooth cat known to the writer that is in a fair state of preservation, with the exception of the California material. No teeth remain with the Florida specimen, while in *S. californicus* we have representatives of all the teeth. Measurements of the alveoli seem to show that they are about the same size in the two, with those of *S. floridanus* a trifle longer in anteroposterior diameter. The alveoli of the canines are practically the same size in both specimens. While the skulls of the *S. floridanus* and *S. californicus*

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are very close in their general aspects, they can be readily distinguished by the posterior position of the posterior nares and the shorter face of *S. californicus,* and possibly by the ridges on the palate. It is probable that if the lower jaw of *S. floridanus* were known, the two species would be still more widely separated.

Smilodon neogaeus is a larger species than *S. californicus,* but in general has the same proportions. The main differences are, the greater anteroposterior diameter of the upper canine, the possession of a single-rooted P_3, the greater length of the inferior diastema, or the posterior position of P_4 and M_1 on the mandible, and the smaller size of M_1 in *S. neogaeus,* and the heavier character of the jaw and small flange of *S. californicus.*

The measurements of the cranium of *S. neogaeus* are in the main larger than in *S. californicus,* with the exception that the canine has a greater anteroposterior diameter and a somewhat less transverse diameter. The most interesting comparison is drawn between the mandibles of these species. It will be noticed that depth of each mandible is the same, while the length in *S. neogaeus* is greater by 30 mm. The difference in form and size is almost solely in increased length of the region of the diastema in *neogaeus. S. californicus* was evidently a much shorter faced form than the South American cat. The coronoid process is also farther forward, but is broader. P_3 is absent in *californicus,* but is in some cases represented by a single-rooted tooth in *neogaeus.* The character of the symphysial region is also different, that of the South American form slanting backward at a considerable angle and lengthening the region of contact, while in the California specimen the slant downward and backward is not so marked and the region of contact forms a large oval surface extending considerably below the ramus.

Smilodon necator Lund[8] is of the same size as *neogaeus,* but differs from it in the breadth and length of face and the greater size of teeth, except the superior canine, which is smaller. *S. californicus* agrees with *S. necator* in the dental formula, but outside of this character it shows no resemblances other than those of *S. neogaeus.*

[8] K. Danske. Vidensk. Selskabs. Afhandl. 1x, pp. 137-208, Pls. XXVIII-XXXVIII.

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TABLE OF MEASUREMENTS.

	S. californicus[a]	*S. floridanus*	*S. neogaeus*	*S. necatur*	*M. gracilis*	*M. mercerii*
Length of skull from occipital condyles to incisive alveoli	290	285	330	330		
Breadth of skull at widest part	208	190	230(?)	230		
Depth of postglenoid tubercle	130	125	160	164		
Length from incisive alveoli to inferior nares	156	136				
Length of skull from behind zygoma to incisive alveoli	198	210	225	245		
Breadth of skull at mastoid process		126	140	143		
Breadth at occip. condyles	64.2	63		60		
Breadth of face at sectorials	143	150		170		
Breadth of face at canines	96.6	94	112(?)	112		
Depth of face at infraorbital margin	49.2	60	53	55		
Depth of zygoma	43	46	43	38		
Vertical diameter of infraorbital foramen	24.4	21	21			
Transverse diameter of infraorbital foramen	15.2	14	15			
Fore and aft space of teeth	133.7	140	163	146	128	
Fore and aft space of molars	49.3	55	63	62		
Breadth fore and aft of superior sectorial	33.4	37	42	43	34	
Length from I^1 to P^4, inclusive	133.7		154.3		128	
Length from I_1 to M_1, inclusive	132		164.5		126	
Breadth fore and aft of P^3	14.4	16	18	18	16	
Breadth fore and aft of superior canine	39.7	40	53	45	28	
Breadth transverse of superior canine	18.5	20		20		
Antero-posterior diameter of P_3			8			
Antero-posterior diameter of P_4	27.8		27.7	35	34	21
Antero-posterior diameter of M_1	29.5		29.4	31	24.5	22.5
Transverse diameter of M_1	14.6		13.3	16		10
Length from I_2 to posterior edge of coronoid process	171.6		207			142
Length from I_2 to posterior side of M_1	124.5		155			105
Length of inferior diastema	62		77.2		46.5	36
Length from posterior edge of condyle to back of M_1	73.8		68			
Depth of symphysis	61.5		66			49
Depth of mandible at P_3	34.5		34.5		35	31
Depth of mandible at shallowest part	33.5					

[a] Mandible No. 10210, cranium No. 10948.

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Machaerodus gracilis Cope [10] from the Port Kennedy Cave deposits is a smaller individual, has a single-rooted P_3, a shorter diastema on the mandible, and a large flange on the lower jaw. *M. mercerii* Cope[11] is smaller than *M. gracilis* and has a double-rooted P_3.

Dinobastis serus Cope[12] is known only from the upper dentition, but is characterized by the shortness of the upper canine and the absence of the inner root of the sectorial.

Smilodon fatalis Leidy[13] is known only from a small portion of the maxillary and the superior sectorial. It is characterized by the low blade of the sectorial and the well developed tubercle anterior to the protostyle. While *S. californicus* shows also an anterior tubercle, the tooth differs so much in size and shape of the protocone that the separation of these two species is not difficult.

MACHAERODUS (?) ISCHYRUS Merriam.

Univ. of Calif. Pub. Geology, Vol. 4, No. 9, p. 171.

This species is known only from a mandible (No. 8140, Univ. Calif. Col. Vert. Palae.) and is characterized by the great reduction of P_3, the presence of a single posterior cusp on P_4, the absence of both metaconid and heel from M_1, the shortness of the diastema, the possession of a prominent flange below the symphysial region, and the abbreviation of the jaw.

This type differs very strongly from the long slender jaws of the South American cats and from *S. californicus*. The presence of P_3 and absence of metaconid and heel from M_1, the shortness of the jaw, and the heavy flange indicate that *S. californicus* and *M. ischyrus* belong to widely separated species if not genera.

FELIS, sp. indet.

Pl. 14, fig. 1.

This specimen (No. 3825, Univ. Calif. Palae. Col.) is represented by a left superior milk sectorial. It was found imbedded

[10] Am. Nat., XIV, pp. 833-858.
[11] Proc. Acad. Nat. Sci. Philadel., 1895, pp. 446-451.
[12] Am. Nat., Vol. XXVIII, pp. 896-897.
[13] Proc. Acad. Nat. Sci. Philad., 1868, pp. 174-176.

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in the Quaternary deposits of the Potter Creek Cave.[14] Associated with it were the remains of *Arctotherium simum, Eucera-therium collinum,* also the remains of deer, camel, horse, and large quantities of rodent bones. Mr. Sinclair has determined the cave deposits as Quaternary.

This specimen belongs to a very large species, probably very close to the African lion in size. Comparison with a young African lion shows how closely the measurements agree. (See table of measurements.) The milk carnassial of the recent mountain lion is much smaller than $\overline{3825}$. The tooth differs markedly from the milk sectorial of *S. californicus,* the latter having but a single protostyle and being somewhat shorter. *M. sivalensis* has two anterior cusps, but the secondary cusp is smaller and less developed than the protostyle. The position and size of the anterior cusps indicate that this tooth belonged to a very large cat of the true *Felis* type. The only true *Felis* known in California that could approach in size such an individual as is represented by the milk tooth $\overline{3825}$ is the imperfectly known *Felis imperialis* Leidy. More material is necessary before anything more than a tentative opinion regarding the affinities of this form can be reached.

Comparative measurements of left superior milk carnassials:

	$\overline{3825}$ From Potter Creek Cave.	$\overline{8762}$ African Lion.	$\overline{8761}$ Puma.	*Machaerodus sivalensis.*
Anteroposterior diameter	24.6 mm.	24.3 mm.	16 mm.	19 mm.
Transverse diameter	8.2	8	4.6	5

FELIS IMPERIALIS Leidy.

Felis imperialis Leidy, U. S. Geol. of Ter., Vol. I, p. 228, pl. XXXI, fig. 3.

The only known specimen of this large species was found twenty-five miles east of San Leandro, California. The exact location is not known. The specimen consists of a fragment of a maxillary showing the second and third premolars and a portion of the alveolus of the canine. It appears to represent a true *Felis* slightly larger than the Bengal tiger.

[14] Sinclair, W. J., Univ. of Calif. Pub. Am. Arch. and Eth., Vol. 2, No. 1.

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FELIS HIPPOLESTES Merriam, C. H.

Pl. 14, figs. 3, 4, 5.

Felis hippolestes Merriam, C.H., Proc. Biol. Soc. Wash., Vol. XI, p. 219, July, 1897.

This species is represented by several specimens. No. 8850 is a large, fine skull, complete except for the lower jaw. It comes from the Quaternary deposits of Samwel Cave, Shasta County, California.

Specimen No. 3819, from the Potter Creek Cave, Shasta County, is only a small portion of the jaw showing P_3, P_4, and M_1. It resembles the modern pumas generally in the form of the teeth. The measurements may show the teeth to be a little larger, both longer and thicker than those of the type *F. hippolestes*. The jaw in this form is rather heavy for a female.

No. 3744, a fragment of the lower jaw from the Potter Creek Cave, contains P_3, P_4, and M_1. The jaw is slender, but the teeth are about the same as in 3819. It may be a female like No. 3819.

A left upper sectorial (No. 4423) from the Potter Creek Cave represents a feline species almost identical with *F. hippolestes* Merriam, C. H., except that it is a trifle larger. Comparison of this specimen with the one from Samwel Cave shows that the latter is somewhat larger.

	No. 4234	No. 8850
Anteroposterior diameter	24.8	26.9
Transverse diameter	11.5	12.5

FELIS FASCIATUS Rafinesque, n. subsp. PARVUS.

Pl. 14, fig. 2.

This specimen (No. 3741, Univ. of Calif. Col. Vert. Palae.) is represented by a part of the right lower jaw with P_3, P_4, and M_1 in place. It is from the Quaternary deposits of Potter Creek Cave, Shasta County, California.

This form resembles most closely a mandible of *F. fasciatus* (U. S. National Museum, No. 58102) from Glendale, Oregon. The mandible of 3741 is a little more slender, not so high, but is as thick through. M_1 is about the size of that in *F. fasciatus*.

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P_4 is a trifle smaller than in *fasciatus*. P_3 is considerably smaller. The space between P_3 and the canine is very short, shorter than in any specimen seen in the National Museum collection. The masseteric fossa is deep and pointed in front. In most other forms it is wider in front.

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EXPLANATION OF PLATE 13.

Smilodon californicus, n. sp.

From Quaternary Beds West of Los Angeles, California.

All figures about one-half natural size (× .55).

Fig. 1.—Left ramus of mandible. No. $\overline{10210}$. A small heel on M_1 does not appear in the figure. Page 157.

Fig. 2.—Left ramus of mandible. No. $\overline{10258}$.

Fig. 3.—Left inferior canine, showing basal tubercle. No. $\overline{10203}$.

Fig. 4.—Superior sectorial of a young individual. No. $\overline{10325}$.

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EXPLANATION OF PLATE 14.

All figures natural size.

Fig. 1.—*Felis*, sp. indet. Left milk sectorial. No. 3825. Quaternary, Potter Creek Cave, Shasta County, California. Page 163.

Fig. 2.—*Felis fasciatus* Rafinesque, n. var. *parvus*. Right ramus of the mandible showing P_3 P_4 M_1. No. 3741. Quaternary, Potter Creek Cave, Shasta County, California. Page 165.

Fig. 3.—*Felis hippolestes* Merriam C. H. Left ramus of the mandible showing P_3 P_4 M_1. No. 3819. Quaternary, Potter Creek Cave, Shasta County, California. Page 165.

Fig. 4.—*Felis hippolestes* Merriam C. H. Left upper sectorial. No. 4423. Quaternary, Potter Creek Cave, Shasta County, California. Page 165.

Fig. 5.—*Felis hippolestes* Merriam C. H. Left mandible. No. 3744. Quaternary, Potter Creek Cave, Shasta County, California. Page 165.

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UNIVERSITY OF CALIFORNIA PUBLICATIONS

BULLETIN OF THE DEPARTMENT OF

GEOLOGY

Vol. 5, No. 11, pp. 171-205 ANDREW C. LAWSON, Editor

TERTIARY FAUNAS OF THE JOHN DAY REGION.

BY

JOHN C. MERRIAM AND WILLIAM J. SINCLAIR.

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INTRODUCTION.

In several publications appearing at intervals since 1901 there have been presented the principal geological and palaeontological results obtained by the University of California expeditions in the John Day region of Oregon. A general statement of the results so far as correlation and faunal relations are concerned has, however, been deferred until all of the available evidence should be obtained from the several fields of investigation in which work has been in progress. The following contribution is based primarily on the collections made by parties from

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the University of California working in the valley of the John Day River during the summers of 1899, 1900, and 1901, and by Messrs. V. C. Osmont and L. S. Davis, who collected along the John Day and in the Crooked River basin in 1900. Particular attention was paid in the field to the study of the vertical range of species, and it is now possible to present some account of the time range of a considerable proportion of the Tertiary fauna of this region, and to offer some suggestions regarding the correlatives of the formations containing mammalian remains.

The writers desire to express their indebtedness to Mr. J. W. Gidley, who has studied the horse material collected from the Mascall and Rattlesnake beds. The John Day rhinoceroses in the University of California collection have been submitted to Professor H. F. Osborn for determination, but his report has been delayed, pending a further revision of the group, especially of the later Oligocene and Miocene North American forms.

STRATIGRAPHIC SUCCESSION OF THE CENOZIC FORMATIONS IN THE JOHN DAY BASIN.

The stratigraphy of the John Day basin has been discussed in a previous paper.[1] The section there described may be expressed in tabular form as shown on the opposite page.

The oldest formation in the basin affording mammalian remains is the John Day, which overlies the plant-bearing Clarno beds. On stratigraphic and palaeontologic grounds the John Day has been subdivided into three divisions: lower, middle, and upper.[2]

The lower division is composed of red, white, and green tuffaceous shales, which weather down into mud-covered dome-like hills. No unconformity has been observed between this division and the Middle John Day, although it is possible that one exists. The brilliant color of the lower beds, their characteristic lithology, and the almost total absence of fossils separate them sharply from the Middle John Day in which vertebrate remains are abundant.

[1] Merriam, J. C. A Contribution to the Geology of the John Day Basin. Bull. Dept. Geol. Univ. Cal., Vol. 2, pp. 269-314.

[2] Merriam, *Ibid.* pp. 293-295.

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AGE	Section in the John Day Basin		Correlatives.
QUATERNARY	Terrace deposits with *Equus* and *Elephas* remains.		Later half of Quaternary.
	Erosion interval (tilting of the Rattlesnake and erosion of John Day Cañon).		Sierran (?)
PLIOCENE	Rattlesnake formation (tuffs, gravels, ashy soil, and rhyolitic lavas).		Not Determined.
	Unconformity (tilting and erosion of the Mascall).		
MIOCENE — LATER MIOCENE	Mascall formation (tuffs, ashes, and possibly gravels).		Pawnee Creek beds, Colorado; Deep River beds, Montana; Ellensberg formation, Washington[3]
MIOCENE — EARLIER MIOCENE	Columbia Lava (basalt and interstratified basaltic tuffs).		Yakima Basalt, Ellensberg quadrangle, Washington.
	Unconformity. Slight folding of the John Day. Interval of erosion.		Harrison formation. Monroe Creek formation. Rosebud formation.
OLIGOCENE	JOHN DAY SERIES: Upper John Day (mainly buff-tinted tuffs. Sands and gravels near top).		
	JOHN DAY SERIES: Middle John Day (drab and bluish-green tuffs).		
	JOHN DAY SERIES: Lower John Day (red, white and green tuffaceous shales).		
	Unconformity.		
EOCENE	Clarno formation (shales, tuffs, andesitic and rhyolitic lavas). The Clarno has yielded an abundant flora but no vertebrate remains have yet been found.	Upper Clarno beds. (Upper Eocene).	Payette formation, Idaho.[4] Manastash formation, Washington.[5]
		Lower Clarno beds. (Lower Eocene).	
	Unconformity.		
CRETACEOUS (MARINE)	Chico formation (sandstones and conglomerates).		Basal Chico at Texas Springs and near Horsetown, California; Phoenix beds at '49 Mines, Oregon.[6]

[3] Knowlton, F. Fossil Flora of the John Day Basin. U. S. G. S. Bulletin 204, pp. 109-110.
[4] *Ibid.* pp. 110-111.
[5] Smith, G. O. Professional paper U. S. G. S. No. 19, p. 16.
[6] Stanton, T. W. Note in Bull. Dept. Geol. Univ. Cal. Vol. 2 p. 284.

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The rocks of the middle division are andesitic tuffs of a characteristic green or greenish-blue color. Thin flows of rhyolitic lava are interbedded with these tuffs at Bridge Creek and in Turtle Cove.

The upper division is composed of tuffs petrographically similar to those of the Middle John Day but prevailingly light buff in color. At a number of localities sands and gravels are found near the top of the formation, indicating a change in the mode of deposition.

No sharp stratigraphic line can be drawn between the Middle and Upper John Day, the color of the beds usually serving for their discrimination in the field. Faunally, the dividing line between them may be fixed by the downward range of *Promerycochoerus* which is not known to occur in the Middle John Day. This limit is for the present regarded as lying about 100 feet above a prominent stratum of coarse gray tuff exposed quite generally near the top of the Middle John Day in Turtle Cove, where, by differential weathering, it usually forms a terrace. The bluish-tinted tuff beds above this stratum contain a rodent fauna practically identical with that occurring lower down in the Middle John Day and are, accordingly, incorporated with the middle division.

Before the extravasation of the Columbia Lava, the John Day formation was subjected to erosion. The surface thus produced is known to have supported a growth of timber in at least one locality. Partly charred and partly silicified wood has been found at the contact of the buff beds with the lava, numerous sticks and stems extending some distance upward into the lower portion of the lava flow. Angular unconformity has been observed between the lava and the John Day, due to gentle folding of the latter formation previous to the outpouring of the lava.

The Columbia Lava is built up of numerous heavy sheets of olivine basalt with relatively insignificant amounts of basaltic tuffs interbedded with the flows.[7] In Oregon, the lava series reaches a thickness of one to two thousand feet.

Resting on the Columbia Lava without observed uncon-

[7] Calkins, F. C. A Contribution to the Petrography of the John Day Basin. Bull. Dept. Geol. Univ. Cal., Vol. 2, p. 159.

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formity is the Mascall formation. The lower beds, from which numerous leaf impressions and poorly preserved fish remains have been obtained, are described by Calkins as fine-grained, chalky rocks, probably in part of organic origin. Grey friable tuffs composed largely of glass particles also form part of the series. The upper beds which yield the mammalian remains are tuffs of light color, fine grain, and harsh texture. At several localities thin basalt flows are interstratified with the lower Mascall beds.

Upon the uptilted and eroded edges of the Mascall there lies a considerable thickness of gravel, tuff and rhyolitic lava which has been named the Rattlesnake formation, from its typical occurrence on Rattlesnake Creek near Cottonwood. The basal gravels of the Rattlesnake contain many pebbles evidently derived from the Columbia Lava. Vertebrate remains have been obtained from both the tuffs and the gravels.

The tuffaceous layers are irregularly bedded but appear to have been worked over by wind, and to have formed soil or dirt beds supporting a considerable growth of plants. In some places they are filled with slender cord-like bodies which evidently represent mineral accumulation about small roots. Along one section of a soil bed a large number of fragments of horse bones and teeth, evidently all belonging to one individual, were scattered for a horizontal distance of ever twenty feet and through one and one-half feet in thickness. The scattered and broken condition of the bones of this individual seem to indicate a long exposure of the remains on a land surface which was being rapidly worked over.

In some sections the prominent rhyolitic bed forms the cap of extensive tables. In other regions, as near Belshaw's ranch, there are at least two hundred feet of gravels above the rhyolite bed.

The close of Rattlesnake deposition marks the beginning of an interval of erosion which may be regarded as the opening event of the Quaternary. It has been suggested that the deformation of the Rattlesnake occurred after the John Day River had established itself in its present course.[8]

[8] Merriam. *Op. cit.*, p. 312.

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Stream terraces are found along the John Day and its main branches, and there are many old alluvial slopes covered with angular rubble. Remains of *Elephas* and *Equus* are preserved in the Quaternary terrace gravels.

HISTORY OF CORRELATION.

The earliest expression of opinion regarding the correlation of the Tertiary formations in the John Day valley seems to have been that of O. C. Marsh[9] in 1875. Of the John Day Marsh wrote: "The typical localities of this Miocene basin are along the John Day River, and this name may very properly be used to designate the lake basin. . . . . The upper beds alone of this series correspond to the deposits in the White River basin. The lower portion also is clearly Miocene, as shown by its vertebrate fauna, which differs in many respects from that above." The Clarno is referred to as "the Eocene beds containing fossil plants." The presence of Pliocene beds above the Miocene is also noted. The so-called Pliocene is evidently the Mascall and Rattlesnake, near the typical exposures of which on Cottonwood Creek Marsh is known to have camped.

Views similar to those of Marsh were entertained by Cope[10] who wrote of "the White River beds of the John Day region". In the same paper the Mascall and Rattlesnake are referred to as "the Loup Fork formation of Cottonwood Creek".

By Clarence King[11] the John Day was correlated with the Truckee group, and both formations were supposed to have been deposited in the same body of water, Pah-Ute Lake. In explanation of this correlation King stated that: "The main reason for classing the whole group" (*i.e.*, Truckee) "as Miocene is that farther north in Oregon, upon John Day, Des Chutes and Crooked Rivers, Professor Marsh's researches have brought to light an immense formation, computed by him to be 3000 or 4000 feet thick, containing numerous vertebrate remains of clearly Miocene type. These Oregon beds are all in inclined position, earlier than basaltic eruptions, and the main material of

[9] Am. Jour. Sci. 3d. ser. Vol. 9, p. 52, 1875.

[10] Observations on the Faunae of the Miocene Tertiaries of Oregon. Bull. U. S. Geol. Surv. of the Terrs., Vol. 5, Article 3, 1879.

[11] U. S. Geol. Exploration of the Fortieth Parallel, Vol. 1, p. 423.

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his whole series, as I have determined by microscopic studies, is of stratified trachytic pumice, tuffs and hyaline sands. The Oregon Miocene is apparently the direct northward continuation of the Nevada formation. Besides the parallelism between the two series is the fact of an overlying unconformable Pliocene in each case". It would seem from this reference to the Pliocene that King possibly identified the Mascall or Rattlesnake with the deposits in his Shoshone Lake. On a later page[12] the following table was presented by King:

MIOCENE.

Contemporaneous

Province of Nevada and Oregon.	Province of Great Plains.
Pah-Ute Lake (Truckee Group, King; John Day Group, Marsh).	Sioux Lake (White River Group, Hayden).

King's correlation was adopted by Cope[13] in his later writings. In 1880 he published the following general account of the geology of the John Day country: "The regions of the John Day River and Blue Mountains furnish sections of the formations of central Oregon. Above the Loup Fork or Upper Miocene there is a lava outflow, which has furnished the materials of a later lacustrine formation, which contains many vegetable remains. The material is coarse, and sometimes gravelly, and it is found on the Columbia River and I think also in the interior basin. Professor Condon, in his unpublished notes, calls this the Dalles Group. It is in turn overlaid by the beds of the second great volcanic outflow. Below the Loup Fork follows the Truckee Group, so rich in extinct mammalia, and below this a formation of shales. These are composed of fine material, and vary in color from a white to a pale brown and reddish-brown. They contain vegetable remains in excellent preservation, and undeterminable fishes.

The *Taxodium* nearly resembles that from the shales at Osino, Nevada, and on various grounds I suspect that these beds form a part of the Amyzon Group (American Naturalist, June, 1880), with the shales of Osino and of the South Park of Colorado.

[12] King. *Op. cit.*, p. 458.
[13] Proc. Am. Phil. Soc., p. 61, 1880.

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Below these is a system of fine-grained sometimes shaly rocks of delicate gray, buff and greenish colors, containing calamites. which Professor Condon calls the Calamite beds. Their age is undetermined."

In his monograph on the Tertiary Vertebrata, Cope[14] writes of the White River and John Day: "The eastern area of this formation is the true White River epoch of Hayden; the western deposits form the Truckee epoch of King. I named this formation the Oregon, but Mr. King's name is the older and must be retained."

"According to Professor Condon, the Truckee formation of Oregon, on the John Day River, rests unconformably on the laminated beds containing *Taxodium* and fish remains, which, as I have suggested on a previous page, may be an extension of the Amyzon shales. These in turn rest on a formation of hard laminated beds, which contain an abundance of calamites, which doubtless belong to the Triassic or Jurassic period. The Truckee beds are, like the true White River, overlaid by the Loup Fork, and this in turn by heavy beds of basalt."

The beds at Van Horn's ranch containing fish remains, which Cope assumed were to be correlated with the Amyzon group, were referred by Lesquereux[15] to the late Miocene and are now known as the Mascall formation. The Calamite beds were placed by Lesquereux in the Eocene and are undoubtedly the Clarno. Cope's error in correlating the beds containing the fish remains with the Amyzon group arose from confusing the Mascall with the Clarno.

In the monograph referred to above,[16] Cope proposes the following table of equivalent European and American horizons:

WEST EUROPE			NORTH AMERICA	
Oeningian	Oeningian	TERTIARY	Loup Fork	Procamelus beds
Tortonian	Falunian			Ticholeptus beds
Langhian				
Aquitanian	Aquitanian		White River	Truckee
Stampian	Tongrian			White River

[14] U. S. G. S. of the Terrs. Report, Vol. 3, p. 15.
[15] Proc. U. S. National Mus., Vol. 11, p. 13, 1889.
[16] Tertiary Vertebrata, table opposite p. 43.

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The term Truckee was later abandoned by him in favor of Marsh's John Day. The change in nomenclature appears in a note on the vertebrate fauna of the Ticholeptus beds published in 1886[17].

"In the Report of the U. S. Geological Survey of the Terrs., Vol. III. p. 18 (1884), I have given some of the characters of this horizon" (i. e., the Ticholeptus beds) "and its fauna. It is intermediate in all respects between the Middle and Upper Miocene formations of the West, as represented by the John Day and Loup Fork beds. It was first explored in the valley of Deep River, Montana, by my assistant, J. C. Isaac, and afterwards by J. L. Wortman on the Cottonwood Creek, Oregon. At the latter locality it is seen to rest on the John Day beds, as stated by Mr. Wortman, and is indicated by the collections made by him." The statement regarding the superposition of the so-called Ticholeptus beds on the John Day should probably be read as "above" rather than "on the John Day". This formation has been termed the Cottonwood beds[18], Loup Fork beds, Amyzon beds[19] and Protolabis beds[20]. In Oregon it is now known as the Mascall formation.

Cope's correlation of the Mascall with the Montana Deep River is rejected by Scott[21], as follows: "I cannot agree with Cope in regarding the strata of western Nebrasca and Cottonwood Creek, Oregon, as referable to the same horizon as those of the Deep River valley in Montana. . . . The reference of the beds developed along Cottonwood Creek and the upper John Day River, in Oregon, to the Deep River horizon, is determined by the occurrence in them of a so-called *Anchitherium* and of a species identified as *Blastomeryx borealis*. It should be noted, however, that the term *Anchitherium* is used in the sense of *Miohippus*, the species from Montana which I have called *A. equinum* is a very different animal and belongs to the group of *A. aurelianense*, of Europe, which it equals in size. *Miohippus*

[17] Am. Nat., Vol. 20, pp. 367-368, 1886.
[18] Bull. Am. Museum of Nat. Hist., Vol. 12, p. 23; also Jour. of Geol., Vol. 9, p. 72.
[19] Cope. Proc. Am. Phil. Soc., 1880, Vol. 19, p. 61.
[20] Wortman. Bull. Am. Mus. Nat. Hist., Vol. 10, pp. 120, 141.
[21] The Mammalia of the Deep River Beds. Trans. Am. Phil Soc., Vol. 17, p. 60, 1893.

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is found in the typical Loup Fork, as well as in the lower series (see Osborn, Bull. Mus. Comp. Zool. Cambridge, Vol. 16, p. 89, under the title *Anchitherium parvulum*). No great weight therefore, can be attached to the occurrence of the genus in the Cottonwood Creek beds. The presence of *Blastomeryx borealis* would, of itself, be insufficient for the correlation of the two localities, but the identification of the species is not at all certain. Besides certain minor differences in the teeth, the limb bones from the Oregon beds indicate the existence there of two species, both of which are much heavier than the Montana forms and are more like others from the Loup Fork of Kansas."

In the same paper [22] the lower strata in the valley of Deep River are referred to the top of the John Day.

Certain "deposits of gravel, clay and volcanic dust,, lying above the lavas of the Columbia River in eastern Washington have been correlated by Russell[23] with the John Day. "Beds of light-colored clay and of white volcanic dust, which have been referred to the John Day system, occur at the White Bluffs of the Columbia, 30 miles above Pasco, and are also well exposed in Naches Valley and near Ellensberg in Yakima County." Knowlton[24] has shown that the leaf-bearing beds above the lava in the vicinity of Ellensberg are the correlatives of the Mascall.

Scott[25] has formulated his views regarding the European equivalents of the White River and John Day in an address delivered before the British Association for the Advancement of Science from which the following extract is taken:

"The White River is Oligocene (Ronzon) and much misunderstanding has come from calling it Miocene. The John Day may be placed in the Lower Miocene, though it is somewhat older than the beds at St. Gerand-le-Puy, and follows the White River with hardly a break. None of the American lacustrines is referable to the Middle Miocene. The Loup Fork is Upper Miocene, the Deep River division corresponding almost exactly to the beds at Sansan and Steinheim. . .".

[22] Scott. *Op. cit.*, p. 60.

[23] Reconnaissance in Southeastern Washington, U. S. G. S. Water Supply and Irrigation Papers, No. 4, 1897.

[24] Ellensberg Folio, U. S. Geol. Atlas, note in descriptive text.

[25] Rept. Brit. Ass. for the Adv. of Sci., 1895, p. 681.

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By Von Zittel[26] the John Day has been placed as the equivalent of the beds at Sansan and Steinheim. The so-called Tricholeptus beds of Cottonwood Creek, Oregon, are correlated with the sands of Eppelsheim and the beds at Pikermi near Athens and Maragha in Persia. The beds at St. Gerand-le-Puy and Ronzon are correlated with the White River, which is referred in part to the Miocene and in part to the Oligocene, while the John Day is called Middle Miocene and the Tricholeptus beds Upper Miocene.

In an extensive correlation table, W. H. Dall[27] has bracketed opposite each of the formations in question what he regards as their equivalents in various parts of the United States, and also the corresponding European horizons. The Oligocene is here admitted as a fourth division of the Tertiary. A part of the table is herewith reproduced:

A	Epochs and Stages	B	Pacific Coast	C	Lake Beds	F	Foreign
4	Miocene	9	Ione formation	4	Loup Fork	5	Helvetian
		10	Sooke beds				
		11	Empire beds				
		12	Astoria sandstone				
		13	Monterey beds	.....	.....		
5	*Transitional*	.....	.....	5	Deep River	6	Sansans beds
	Oligocene						
6	*a.* Upper or Chipolan	14	Tunnel Point beds (?)	6	John Day	7	Aquitanian
		15	Astoria shales				
7	*Transitional*	.....	.....	7	Protoceras bed	8	Tongrian
8	*b.* Lower or Vicksburgian	16	Aturia bed	8 9 10	White River Upper White River Middle White River Lower	9	Ligurian

[26] Handbuch der Palaeontologie, Band 4, s. 65-66.

[27] Eighteenth Annual Report, U. S. G. S., Part 2, table opposite p. 334.

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W. D. Matthew[28] has suggested as probable an "overlap to some extent" of the Protoceras beds on "the Lower Miocene John Day". "The Cottonwood basin, containing a higher fauna", is made "equivalent to the Deep River (Cope and Wortman) or Loup Fork (Scott)". In the correlation table published by Matthew[29], the Diceratherium beds[30] of the John Day and a portion of the Promerycochoerus beds[30] are made the equivalent of Horizon C of the Colorado White River section, which is referred in part to the Oligocene and in part to the Lower Miocene. The Rattlesnake is spoken of as "the loose gravels overlying the Cottonwood beds" and is placed above the Loup Fork and referred to the Pliocene. In a later paper Matthew[31] has called the Diceratherium beds Upper Oligocene and the Promerycochoerus beds Lower Miocene. The Mascall is placed in the Middle Miocene. As the latter reference is framed in accordance with the four-fold subdivision of the Tertiary, it is, perhaps, less discordant with Knowlton's[32] views regarding the Upper Miocene age of the Mascall than would at first appear.

The following table of European and American equivalents has been published by Osborn:[33]

Miocene	Upper	Tortonien	Loup Fork
	Middle	Helvetien	Lower Loup Fork and
	Lower	Langhien	Upper John Day
Oligocene	Upper	Aquitanien	Lower John Day (Diceratherium beds)
	Lower	Tongrien { Stampien / Infra-Tongrien }	White River

[28] A Provisional Classification of the Fresh-water Tertiary of the West. Bull. Am. Mus. Nat. Hist., Vol. 12, Article 3.

[29] *Ibid.*, p. 23.

[30] See under heading: The John Day, *Palaeontological classification.*

[31] Notice of Two New Oligocene Camels. Bull. Am. Mus., Vol. 20, p. 214, 1904.

[32] Bulletin U. S. G. S., No. 204, p. 108.

[33] Correlation Between Tertiary Mammal Horizons of Europe and America, with Third Trial Sheet, Annals N. Y. Acad. Sci., Vol. 13, pp. 1-72, 1900.

The Geological and Faunal Relations of Europe and America During the Tertiary Period and the Theory of the Successive Invasions of an African Fauna. Science, n. s., Vol. 11, p. 561, 1900.

See also Osborn, Bull. Am. Mus. Vol. 23, pp. 237-253, 1907, issued since the preparation of present article. The Lower John Day is placed in the second phase of the Middle Oligocene, equivalent to the Leptauchenia beds and Protoceras sandstones. The Middle John Day is referred to the Upper Oligocene, and is believed to be closely equivalent faunally to the Aquitanien of France (St. Gerand-le-Puy). The Upper John Day is regarded as transitional between Oligocene and Miocene. The Mascall is placed in the earlier Miocene. The Rattlesnake is referred to the Lower and Middle Pliocene.

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A still later table is the following by Hatcher:[34]

Miocene	Loup Fork	Goodnight = Palo Duro = Ogalalla Nebrasca = Upper Deep River Harrison = Hiatus between Lower and Upper Deep River.
	Arikaree	Monroe Creek = Upper John Day and Lower Deep River. Gering Sandstone = Lower John Day
Oligocene = White River		Leptauchenia Clays, including Protoceras Sandstones. Oreodon Clays, including Metamynodon Sandstones. Titanotherium Sandstones and Clays.

The reasons which have governed the determinations of geologic age and stratigraphic equivalency expressed in the table on page 173 of the present paper are stated at length in the following chapters:

THE JOHN DAY.

Palaeontological Classification.—Two faunas may be recognized in the John Day, corresponding to the middle and upper stratigraphic subdivisions. The Lower John Day will probably prove to be faunally distinct from the beds above, but until its fauna is better known it must be left without a palaeontologic designation.

Wortman[35] has proposed a subdivision of the series into lower or Diceratherium beds and upper or Merycochoerus beds, the former corresponding to the middle and the latter to the upper of the three subdivisions now recognized. The value of the term "Diceratherium beds" is greatly diminished by the difficulty of identifying *Diceratherium* in the field, owing to the usual fragmentary character of much of the rhinoceros material encountered. As yet it is also not altogether certain that the genus is confined to the Middle John Day.

The palaeontological designation of the Upper John Day[36] has

[34] Proc. Am. Phil. Soc., Vol. 41, p. 118, 1902.

[35] Extinct Camelidae of North America. Bull. Am. Mus. Nat. Hist., Vol. 10, p. 120.

[36] Merycochoerus beds. Wortman. Bull. Am. Mus., Vol. 10, p. 120.
Paracotylops beds. Merriam. Bull. Dept. Geol. Univ. Cal., Vol. 2, p. 296.
Promerycochoerus beds. Matthew. Memoirs Am. Mus., Vol. 1, pt.7, legend of fig. 19, p. 399.

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varied considerably owing to changes in the generic name of its characteristic oreodent, which has been shown by Matthew[37] and Douglass[38] to belong not to *Merycochoerus* but to a distinct genus named by the latter *Promerycochoerus.*

It has been suggested[39] that the sands, gravels and tuffs at the top of the Upper John Day may represent a third faunal subdivision. They are typically exposed on Johnson and Bologna Creeks, on Bridge Creek, and in the upper end of Haystack Valley, and are characterized by numerous remains of *Miolabis* (*Paratylopus*). Until the fauna of these beds is better known it may be best to include them with the Promerycochoerus horizon.

The Total Fauna.—For convenience in reference, a complete list of John Day vertebrate species is appended. The list is by no means a final one, and it is to be expected that numerous changes will be made as a complete revision of the fauna progresses.

CARNIVORA.

CANIDAE.

Paradaphaenus cuspigerus (Cope) ..... American Museum*
Paradaphaenus, sp. indesc. ..... American Museum
(*Amphicyon hartshornianus* in part).
Nothocyon geismarianus (Cope) ..... American Museum
Nothocyon geismarianus mollis Merriam, J. C. ..... University of California
Nothocyon lemur (Cope) ..... American Museum
Nothocyon latidens (Cope) ..... American Museum
Temnocyon altigenis Cope ..... American Museum
Temnocyon wallovianus Cope ..... American Museum
Temnocyon ferox Eyerman ..... Princeton University
Mesocyon coryphaeus (Cope) ..... American Museum
Mesocyon josephi (Cope) ..... American Museum
Mesocyon brachyops Merriam, J. C. ..... University of California
Hyaenocyon basilatus Cope ..... American Museum
Hyaenocyon sectorius Cope ..... American Museum
Oligobunis crassivultus Cope ..... American Museum
Enhydrocyon stenocephalus Cope ..... American Museum
Philotrox condoni Merriam, J. C. ..... University of California
Cynodictis (?) oregonensis Merriam, J. C. ..... University of California

MUSTELIDAE.

Parictis primaevus Scott ..... Princeton University

[37] Matthew. *Op. cit.*
[38] Douglass. Am. Jour. Sci., 4th ser., Vol. 11, p. 82, 1901.
[39] Sinclair. Jour. of Geology, Vol. 9, p. 706, 1901.
* *Location of type specimen.*

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FELIDAE.

Dinictis cyclops Cope ..... American Museum
Archaelurus debilis Cope ..... American Museum
Archaelurus debilis major Merriam, J. C. ..... University of California
Nimravus gomphodus Cope ..... American Museum
Nimravus confertus Cope ..... American Museum
Pogonodon davisi Merriam, J. C. ..... University of California
Pogonodon brachyops Cope ..... American Museum
Pogonodon platycopis Cope ..... American Museum
Hoplophoneus cerebralis Cope ..... American Museum
Hoplophoneus strigidens Cope ..... American Museum

RODENTIA.

SCIURIDAE.

Sciurus wortmani Cope ..... American Museum
Sciurus ballovianus Cope ..... American Museum

HAPLODONTIDAE.

Allomys (*Meniscomys*) *hippodus* Cope ..... American Museum
Allomys (*Meniscomys*) *liolophus* Cope ..... American Museum
Allomys (*Meniscomys*) *cavatus* Cope ..... American Museum
Allomys (*Meniscomys*) *nitens* Marsh, var. *multiplicatus* Cope. Yale University
Mylagaulodon angulatus Sinclair ..... University of California

CASTORIDAE.

Steneofiber gradatus Cope ..... American Museum
Steneofiber peninsulatus Cope ..... American Museum

GEOMYIDAE.

Pleurolicus sulcifrons Cope ..... American Museum
Pleurolicus leptophrys Cope ..... American Museum
Pleurolicus diplophysus Cope ..... American Museum
Entoptychus planifrons Cope ..... American Museum
Entoptychus cavifrons Cope ..... American Museum
Entoptychus minor Cope ..... American Museum
Entoptychus lambdoideus Cope ..... American Museum
Entoptychus crassiramis Cope ..... American Museum
Entoptychus rostratus Sinclair ..... University of California
Entoptychus sperryi Sinclair ..... University of California

MURIDAE.

Peromyscus nematodon (Cope)[40] ..... American Museum
Peromyscus parvus Sinclair[40] ..... University of California
Paciculus lockingtonianus Cope ..... American Museum
Paciculus insolitus Cope ..... American Museum

LEPORIDAE.

Lepus ennisianus Cope[40] ..... American Museum

[40] Primitive forms which might not be referred to existing genera if better known.

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PERISSODACTYLA.

EQUIDAE.

Mesohippus praestans (Cope) ..... American Museum
Mesohippus equiceps (Cope) ..... American Museum
Mesohippus brachylophus (Cope) ..... American Museum
Mesohippus longicristis (Cope) ..... American Museum
Mesohippus condoni Leidy ..... U. S. National Museum
Mesohippus anceps (Marsh) ..... Yale University
Mesohippus annectens (Marsh) ..... Yale University
Mesohippus acutidens Sinclair ..... University of California

LOPHIODONTIDAE.

? Colodon (*Lophiodon*) *occidentalis* Leidy..... U. S. National Museum

TAPIRIDAE.

Protapirus robustus Sinclair..... University of California

RHINOCEROTIDAE.

Aceratherium pacificum Leidy..... U. S. National Museum
Aceratherium hesperium Leidy..... U. S. National Museum
Aceratherium truquianum Cope..... American Museum
Aceratherium tubifer Cope..... American Museum
Aceratherium annectens Marsh..... Yale University
Diceratherium armatum Marsh ..... Yale University
Diceratherium nanum Marsh..... Yale University

INDETERMINATE.

Daeodon shoshonensis Cope ..... American Museum

CHALICOTHERIDAE.

Moropus distans Marsh..... Yale University
Moropus senex Marsh ..... Yale University

ARTIODACTYLA.

ELOTHERIIDAE.

Elotherium humerosum Cope ..... American Museum
Elotherium imperator Leidy..... U. S. National Museum
Elotherium calkinsi Sinclair..... University of California

SUIDAE.

Thinohyus (*Bothrolabis*) *pristinus* Leidy..... U. S. National Museum
Thinohyus (*Bothrolabis*) *trichaenus* Cope..... American Museum
Thinohyus (*Bothrolabis*) *rostratus* Cope..... American Museum
Thinohyus (*Bothrolabis*) *subaequans* Cope
Condon collection, University of Oregon
Thinohyus (*Bothrolabis*) *decedens* Cope
Condon collection, University of Oregon
Supplementary type, University of California
Thinohyus (*Bothrolabis*) *lentus* Marsh..... Yale University
Thinohyus (*Bothrolabis*) *socialis* Marsh..... Yale University
Thinohyus (*Bothrolabis*) *osmonti* Sinclair..... University of California

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MERYCOIDODONTS.

Agricochoerus trifrons Cope.....American Museum
Agriochoerus guyotianus Cope.....American Museum
Agriochoerus ryderanus Cope.....American Museum
Agriochoerus ferox (Cope).....American Museum
Eporeodon occidentalis Marsh.....Yale University
(*Eucrotaphus jacksoni* Leidy, part
Eucrotaphus major Leidy, part
Eporeodon occidentalis leptacanthus (Cope).....American Museum
Eporeodon occidentalis pacificus (Cope).....American Museum
Eporeodon trigonocephalus (Cope).....American Museum
Eporeodon major longifrons (Cope).....American Museum
Eporeodon socialis Marsh.....Yale University
Promerycochoerus superbus (Leidy),.....U. S. National Museum
(*temporalis* Bettany)
Promerycochoerus chelydra (Cope).....American Museum
Promerycochoerus macrostegus (Cope).....American Museum
Promerycochoerus leidyi (Bettany)
Sedgwickian Museum, Cambridge, England

CAMELIDAE.

Miolabis (*Paratylopus*) *sternbergi* (Cope).....American Museum
Miolabis (*Paratylopus*) *cameloides* (Wortman).....American Museum

HYPERTRAGULIDAE.

Hypertragulus calcaratus (*?*) Cope[41].....American Museum
Allomeryx planiceps Sinclair[42].....University of California

TESTUDINATA.

TESTUDINIDAE.

Stylemys oregonensis Leidy
(*S. nebrascensis* Cope) Condon collection, University of Oregon

SQUAMATA.

BOIDAE.

Ogmophis oregonensis Cope.....American Museum

The Fauna of the Lower Division.—The lower John Day has proved to be almost devoid of fossil remains, although careful search was made for them at a number of localities. The following forms are represented in the University of California's collections by fragmentary specimens too poor for specific determination:

[41] Not *calcaratus* but an undescribed species, Matthew, Bull. Am. Mus., Vol. 16, p. 316. *H. hesperius* of Hay's catalogue, Bull. 179, U. S. G. S., p. 675.

[42] The characters cited in the original description of this genus (Sinclair 1905) are, perhaps, insufficient to warrant separating it from *Hypertragulus*. It is retained for the present, pending a revision of the group.

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Elotherium (large species).
Rhinoceros (genus and species indet.)

Mr. L. S. Davis remembers finding the skull of a Merycoidodont in the beds of this horizon some years ago, but definite information concerning it is not now obtainable.

The Fauna of the Middle Division.—The following list of species from the Diceratherium beds is based on material brought together by University of California parties collecting with the vertical distribution of species particularly in mind:

Temnocyon altigenis Cope.
Nothocyon latidens (Cope).
Nothocyon lemur (Cope).
Nothocyon geismarianus mollis Merriam, J. C.
Mesocyon coryphaeus (Cope).
Mesocyon josephi (?) (Cope).
Philotrox condori Merriam, J. C.
Cynodictis (?) *oregonensis* Merriam, J. C.
Archaelurus debilis major Merriam, J. C.
Nimravus gomphodus Cope.
Allomys nitens Marsh.
Allomys hippodus (Cope).
Allomys cavatus (Cope).
Allomys liolophus (Cope).
Steneofiber peninsulatus Cope
Steneofiber gradatus Cope.
Peromyscus nematodon (Cope).
Peromyscus parvus Sinclair.
Pleurolicus (*?*) sp.
Entoptychus planifrons Cope.
Entoptychus cavifrons Cope.
Entoptychus crassiramis Cope.
Entoptychus minor Cope.
Lepus ennisianus Cope.
Rhinoceros (genera and species not yet determined).
Mesohippus equiceps (Cope).
Elotherium sp.
Thinohyus (*Bothrolabis*) *osmonti* Sinclair.
Thinohyus (*Bothrolabis*) *decedens* Cope.
Thinohyus lentus (*?*) Marsh.
Agriochoerus guyotianus Cope.
Agriochoerus sp.
Eporeodon occidentalis Marsh.
Eporeodon occidentalis pacificus (Cope).
Allomeryx planiceps Sinclair.
Hypertragulus sp.
Stylemys sp.

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Owing to the characteristic color of the matrix of the Middle John Day it has been possible to expand the list of species peculiar to this horizon considerably by an examination of the type material in the Cope collection at the American Museum of Natural History. Judging from the color of the matrix, the following type specimens are probably from the Middle John Day:

Nothocyon geismarianus (Cope).
Nothocyon lemur (Cope).
Temnocyon altigenis Cope.
Mesocyon coryphaeus (Cope)
Archaelurus debilis Cope.
Nimravus gomphodus Cope.
Steneofiber peninsulatus Cope.
Steneofiber gradatus Cope.
Pleurolicus leptophrys Cope.
Entoptychus planifrons Cope.
Entoptychus minor Cope.
Entoptychus lambdoideus Cope.
Allomys hippodus (Cope).
Allomys cavatus (Cope).
Mesohippus equiceps (Cope).
Thinohyus (Bothrolabis) pristinus Cope.
Thinohyus (Bothrolabis) rostratus Cope.
Eporeodon occidentalis leptacanthus (Cope).

To these should be added *Pogonodon platycopis* Cope, the only known specimen of which was collected by Mr. L. S. Davis from the Middle John Day in Turtle Cove.

Combining both of these lists, the Middle John Day fauna, so far as known, contains the following forms:

Temnocyon altigenis Cope.
Nothocyon latidens (Cope).
Nothocyon lemur (Cope).
Nothocyon geismarianus (Cope).
Nothocyon geismarianus mollis Merriam, J. C.
Mesocyon coryphaeus (Cope).
Mesocyon josephi (*?*) (Cope).
Philotrox condoni Merriam, J. C.
Cynodictis (*?*) *oregonensis* Merriam, J. C.
Archaelurus debilis Cope.
Archaelurus debilis major Merriam, J. C.
Nimravus gomphodus Cope.
Pogonodon platycopis Cope.
Allomys nitens Marsh.
Allomys hippodus (Cope).

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Allomys cavatus (Cope).
Allomys liolophus (Cope).
Steneofiber peninsulatus Cope.
Steneofiber gradatus Cope.
Peromyscus nematodon (Cope).
Peromyscus parvus Sinclair.
Pleurolicus (*?*) sp.
Pleurolicus leptophrys Cope.
Entoptychus planifrons Cope.
Entoptychus minor Cope.
Entoptychus cavifrons Cope.
Entoptychus crassiramis Cope.
Entoptychus lambdoideus Cope.
Lepus ennisianus Cope.
Rhinoceros, species indet.
Mesohippus equiceps (Cope).
Elotherium sp.
Thinohyus (*Bothrolabis*) *osmonti* Sinclair.
Thinohyus (*Bothrolabis*) *decedens* Cope.
Thinohyus (*Bothrolabis*) *pristinus* Cope.
Thinohyus (*Bothrolabis*) *rostratus* Cope.
Thinohyus lentus (*?*) Marsh.
Agriochoerus guyotianus Cope.
Agriochoerus sp.
Eporeodon occidentalis Marsh.
Eporeodon occidentalis pacificus (Cope).
Eporeodon occidentalis leptacanthus (Cope).
Allomeryx planiceps Sinclair.
Hypertragulus sp.
Stylemys sp.

The Middle John Day is characterized by abundant remains of *Eporeodon*, especially of the two smaller species *occidentalis* and *pacificus*, and by a great number of rodents, which have been obtained principally at two horizons, one at about the middle and the other at the top of the Diceratherium beds. Both horizons contain practically the same fauna. Next to *Eporeodon* in abundance the most common form is a *Hypertragulus*, fragmentary specimens of which occur at almost every exposure. Rhinoceros material is fairly abundant but usually fragmentary and possibly represents other genera in addition to *Diceratherium*. The smaller pigs of the genus *Thinohyus* are most common in the middle beds, but it can not yet be determined whether they are confined to this horizon.

The Fauna of the Upper Division.—The following are typical

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forms from the Upper John Day. The determinations are based on material in the University of California collection.

Nothocyon lemur (Cope).
Temnocyon altigenis Cope.
Mesocyon coryphaeus (Cope).
Mesocyon brachyops Merriam, J. C.
Pogonodon davisi Merriam, J. C.
Entoptychus planifrons Cope.
Entoptychus cavifrons Cope.
Entoptychus rostratus Sinclair.
Entoptychus sperryi Sinclair.
Lepus ennisianus Cope.
Rhinoceros (genera and species not yet determined).
Mesohippus equiceps (Cope).
Mesohippus acutidens Sinclair.
Protapirus robustus Sinclair.
Elotherium calkinsi Sinclair.
Elotherium sp.
Agriochoerus ferox (Cope).
Eporeodon sp.
Promerycochoerus superbus (Cope).
Promerycochoerus chelydra (*?*) (Cope).
Hypertragulus sp.
Stylemys, sp.

The types of the following species not represented by material in the University of California collection are known with more or less certainty to have been found in the Upper John Day beds.

Temnocyon ferox Eyerman[43].
Mesohippus praestans (Cope)[44]
Eporeodon trigonocephalus (Cope)[45].
Eporeodon major longifrons (Cope)[46].
Promerycochoerus macrostegus (Cope)[47].
Promerycochoerus leidyi (Bettany)[48]

The gravels and tuffs at the top of the Upper John Day which have been referred to on a preceding page as possibly constituting a separate faunal horizon have afforded the following forms:

Mylagaulodon angulatus Sinclair.
Protapirus sp.
Miolabis (*Paratylopus*) *cameloides* (Wortman).

[43] Princeton University collection. Upper John Day, Turtle Cove. Communicated by Professor W. B. Scott.
[44] American Museum collection. Buff-colored matrix.
[45] American Museum collection. North Fork of the John Day River. The matrix is the characteristic buff-colored tuff of the upper division.
[46] Same locality as *E. trigonocephalus.*
[47] American Museum collection. Bridge Creek. The horizon is probably the Promerycochoerus beds.
[48] Bridge Creek. Probably from the Promerycochoerus beds.

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The type of *Miolabis* (*Paratylopus*) *sternbergi* is stated by Wortman to be "from the lower beds of the John Day Valley." (=Diceratherium beds of Wortman). The matrix investing the skull is, however, quite unlike the Middle John Day tuffs, and resembles the uppermost part of the Upper John Day in which camel remains are particularly abundant. For the present it is omitted from the faunal list of either horizon.

Combining the various partial lists of Upper John Day species, the following forms may be regarded as characteristic of this division:

Nothocyon lemur (Cope).
Temnocyon altigenis Cope.
Temnocyon ferox Eyerman.
Mesocyon coryphaeus (Cope).
Mesocyon brachyops Merriam, J. C.
Pogonodon davisi Merriam, J. C.
Entoptychus planifrons Cope.
Entoptychus cavifrons, Cope.
Entoptychus rostratus Sinclair.
Entoptychus sperryi Sinclair.
Lepus ennisianus Cope.
Mylagaulodon angulatus Sinclair.
Rhinoceros.
Mesohippus equiceps (Cope).
Mesohippus acutidens Sinclair.
Mesohippus praestans (Cope).
Protapirus robustus Sinclair.
Protapirus sp.
Elotherium calkinsi Sinclair.
Elotherium sp.
Agriochoerus ferox (Cope).
Eporeodon sp.
Eporeodon trigonocephalus (Cope).
Eporeodon major longifrons (Cope).
Promerycochoerus superbus (Cope).
Promerycochoerus chelydra (Cope).
Promerycochoerus macrostegus (Cope).
Promerycochoerus leidyi (Bettany).
Hypertragulus sp.
Miolabis (*Paratylopus*) *cameloides* (Wortman).
Stylemys sp.

Promerycochoerus is the most common form in the Upper John Day, and is not known from the middle division. Its absence from the middle division affords an important means of discriminating the horizons in the field. Like *Promerycochoerus*,

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Protapirus is also unrepresented in the Middle John Day. The introduction of these two genera may be explained by their immigration from some other province, as they are without known ancestral forms in the Middle John Day. *Agriochoerus* decreases in abundance in the Upper John Day, where it is represented by bizarre forms like *A. ferox*. Large elotheres are more common than in the Diceratherium beds. The smaller hogs have not been found in the upper division. Rodents are not well represented. Camels have been found only in the uppermost beds of the series. Plains and forest types occur together in the same beds.

Age.—Stratigraphically, the John Day occupies a position between the Upper Clarno (Upper Eocene) and the Columbia Lava. From the latter it is separated by an interval of deformation, and sub-aerial erosion. Before considering the age of the John Day it will be advisable to present briefly what is known regarding the age of the lava.

The Columbia Lava is evidently referable to the earlier Miocene, as it is overlain by the Mascall of the later Miocene. Its correlative is the Yakima basalt of the Ellensberg quadrangle, which bears the same relation to the Ellensberg formation that the Columbia Lava does to the Mascall, the equivalent of the Ellensberg. By Smith[49] the age of the Yakima basalt is fixed as early or middle Miocene from the fact that the basalt rests unconformably on the Manastash formation (Upper Eocene= Clarno) without the intervention of the John Day.

The time equivalent of the unconformity at the top of the John Day can not be accurately measured. At a number of localities the upper beds are wanting, the lava resting on the Middle John Day. Elsewhere, the erosion is represented by gulches carved into the John Day tuffs and preserved beneath the lava cap. Taken in connection with the great thickness of the lava it seems reasonable to regard the volcanic and erosion intervals together as equivalent to a considerable part of the earlier Miocene.

A strict adherence to the three-fold subdivision of the Tertiary would necessitate placing the John Day in the Lower

[49] G. O. Smith. Professional Paper U. S. G. S., No. 19, p. 16.

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Miocene and the Columbia Lava in the Middle Miocene, since the former rests on the Upper Eocene and the latter is overlain by beds determined from their flora as Upper Miocene. Following the four-fold division which is becoming more and more generally accepted by American geologists, the John Day is referable mainly if not entirely to the Oligocene, and a study of its fauna has shown the propriety of such reference. "Taken together, the Canidae and Felidae of the John Day represent a stage of evolution somewhat more advanced than that reached in the White River and less advanced than that of the Loup Fork. Compared with the known faunas of Europe they appear to be not older than the Middle Oligocene of Fontainbleau and not as young as the Middle Miocene of Sansan".[50] It is not yet possible to speak so definitely regarding the degree of advancement of other phyla in the John Day fauna, but the persistence of primitive types (*Elotherium, Agriochoerus, Mesohippus, Protapirus*) and the entire absence of the hypsodont camels and horses characteristic of the Middle and Upper Miocene of North America is certainly striking, and, when combined with the stratigraphic evidence just presented, favors the reference of the John Day formation mainly to the Oligocene, although it does not exclude the possibility that the Upper John Day may overlap in part on the Lower Miocene, of which the fauna is at present incompletely known[51].

[50] Merriam, J. C. Univ. Cal. Publ. Geol., Vol. 5, p. 64.

[51] Peterson, O. A. The Agate Spring Fossil Quarry. Annals Carnegie Museum, Vol. 3, pp. 487-494, 1906. The Miocene Beds of Western Nebraska and Eastern Wyoming and their Vertebrate Fauna. Annals Carnegie Mus., Vol. 4, No. 1, March 21, 1907.

Matthew, W. D. A Lower Miocene Fauna from South Dakota. Bull. Am. Mus. Nat. Hist., Vol. 23, p. 169, March 14, 1907.

The recent papers of Peterson and Matthew, appearing since this article was prepared, have shown the existence on the eastern side of the Cordilleran range of early Miocene faunas closely related to that of the John Day. In both western Nebraska and South Dakota faunas are found containing generic types previously known only from the John Day; but in both of these regions the stage of evolution of the forms most closely related to John Day types, as also of the total assemblage of forms, seems a little more advanced than that of the John Day. As the eastern and western faunas were quite distant from each other geographically, and might therefore be expected to differ somewhat, it is not impossible that the earlier portion of the Miocene beds east of the Cordilleran range corresponds in time to the upper portion of the John Day. A more complete knowledge of all of these faunas will be necessary before their exact relationships can be determined, and most important in this connection is the study of scattered patches of middle Tertiary beds which are geographically intermediate.

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As all the John Day species, so far as known at present, appear to be peculiar to the Oregon province, attempts at close correlation have failed. Owing to the lack of common species and the fact that it is often impossible to decide whether certain species are more advanced than others within the limits of the same genus, it is unsafe to base any attempt at very close correlation on the presence of common genera alone.

With the close of the John Day epoch, the total extinction of many genera and even families took place in Oregon. As examples may be cited *Mesohippus, Elotherium, Agriochoerus, Eporeodon, Protapirus,* the Carnivora, and many of the Rodentia. Not a single species survived. Just how the process of extinction operated in the region under discussion, whether by the dying out of long persistent stocks, or by emigration and by transformation in the ordinary processes of evolution is not fully apparent. This faunal break exceeds in importance all differences existing between the lesser subdivisions of the John Day series.

THE MASCALL.

Fauna.—In discussing the Mascall fauna, the possibility of mixture with the overlying Rattlesnake must generally be considered, since bones which have weathered out of the Rattlesnake gravels are frequently found resting on the Mascall, and as most of the material from the latter formation is detached from the matrix it is often very difficult to avoid confusing the two faunas.

A list of the species previously reported and probably derived from these beds is given below. Those marked with an asterisk may possibly be Rattlesnake.

Lutrictis lycopotamicus Cope.
Archaeohippus ultimus (Cope).
Parahippus brevidens (Marsh).
Protohippus medius Cope.
Protohippus avus Marsh.
Pliohippus spectans Cope.
Merychippus isonesus (Cope).
* *Neohipparion occidentale* (Leidy).
* *Neohipparion sinclairi* (Wortman).
Aceratherium oregonense (Marsh).
* *Platygonus rex* Marsh.

* Possibly Rattlesnake.

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Promerycochoerus obliquidens (Cope).
Merycochoerus sp[52].
Miolabis transmontanus Cope.
Alticamelus altus (Marsh).
Palaeomeryx borealis (Cope).
Plioplarchus septemspinosus Cope.

A number of these forms are not represented in the University of California collection and further exploration will be necessary before the two faunas can be fully separated.

Remains of the following species were collected by the University parties at localities where there can be little doubt of their Mascall origin. A large amount of material is unfortunately too fragmentary to permit of specific determination. To this list there is added the type of *Tephrocyon rurestris* (Condon), which is known to be from the Mascall beds.

Canis sp.
Tephrocyon rurestris (Condon).
Mylagaulus sp[53].
Steneofiber sp.
Peromyscus (?) sp.
Lepus sp.
Mastodon sp.
Archaeohippus ultimus (Cope).
Archaeohippus, sp indesc.
Parahippus brevidens (Marsh).
Neohipparion, sp indet.
Pliohippus (*?*) sp.
Merychippus isonesus (Cope).
Merychippus relictus (Cope).
Rhinoceros, sp. and genus indet.
Camelid[54].
Cervine (*Palaeomeryx?*) sp. *a*.
Cervine (*Palaeomeryx?*) sp. *b*.
Merycoidodont[55].
Gravigrade edentate.
Clemmys saxea Hay.
Plioplarchus septemspinosus Cope[56].

[52] Matthew. Bull. Am. Mus., Vol. 12, p. 72.
[53] Collected by Mr. L. S. Davis for Professor K. A. von Zittel from the Mascall near Dayville. A part of the maxilla supporting P^4.
[54] Astragali and calcanea. Size of *Alticamelus altus*.
[55] The presence of a small Merycoidodont is indicated by a mandibular fragment with the greater part of the milk dentition from the Mascall near Dayville. A caniniform premolar was obtained from the Mascall beds on the divide between Camp Creek and Crooked River.
[56] From the leaf-bearing beds of the lower part of the Mascall near the old Van Horn ranch. A single species from this locality.

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A comparison of the Mascall and John Day faunas brings out a number of important contrasts. With the exception of *Lepus* and *Peromyscus*[57], few genera survived the interval of faunal migration and extinction at the close of the John Day, notably *Promerycochoerus, Miolabis* and *Steneofiber*. With the repopulation of the region, hypsodont horses and large camels adapted to existence on grassy plains appear. With these are associated proboscideans and deer of which no ancestral forms are known in the John Day. Evidently a large proportion of the Mascall fauna came into Oregon after the basalt floods had ceased, migrating from other provinces, where its evolution took place during the time of extravasation of the lava or in even earlier time.

Age.—Knowlton has referred the Mascall to the Upper Miocene, basing this conclusion on the affinities and relationships of the forty or more species of plants confined to this formation, but he remarks that if dependence were placed on the distribution of those species which are not confined to the Mascall, "the tendency would be to regard them as not younger than Lower Miocene, or even possibly as old as the Upper Eocene."[58] The Mascall has been correlated by him with the Ellensberg formation[59]. A previous correlation with the auriferous gravels of California is no longer retained.[60]

The Mascall fauna has attained about the same stage of evolution as the faunas of the Pawnee Creek and Deep River horizons of Colorado and Montana, respectively. *Merychippus isonesus* is common to all three[61], while *Parahippus brevidens* (*Desmatippus crenidens* Scott) is common to the Deep River and Mascall. This evidence is deemed sufficient for approximate correlation of the three sets of beds. Both faunal and stratigraphic evidence favors the reference of the Mascall to the middle or later portion of the Miocene.

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[57] See foot-note 40 on p. 185.

[58] Knowlton. Fossil Flora of the John Day Basin. Bull. 204, U. S. G. S., p. 108.

[59] Ellensberg quadrangle, U. S. G. S. Atlas. Note in text.

[60] Bulletin 204, U. S. G. S., pp. 107-108.

[61] Listed by Matthew from the Deep River. Memoirs Amer. Mus., Vol. 1, p. 374.

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THE RATTLESNAKE.

The type specimens of the following species are supposed to have been derived from the Rattlesnake beds:

Neohipparion occidentale (Leidy)[62].
Neohipparion sinclairi (Wortman)[62].
Platygonus rex Marsh[63].

To these should be added, from specimens in the University of California collection *Pliohippus supremus* (Leidy), some indeterminate rhinoceros material, a large hog, a camel of the size of *Alticamelus altus,* fragmentary remains of a smaller camel, and portions of the carapace and plastron of a tortoise (*Clemmys hesperia* Hay.)

The known fauna of the Rattlesnake is too scanty to afford a good basis for age determination or to serve satisfactorily for purposes of correlation. It is evidently pre-Pleistocene, and as the Rattlesnake is separated from the Mascall by a considerable interval of erosion its age may be fixed with some degree of probability as Pliocene.

[62] "From the loose gravels overlying the Cottonwood beds." Matthew. Bull. Am. Mus., Vol. 12, p. 70. This reference was based on Wortman's recollection of his collections made twenty years previous to the publication of Matthew's list. Communicated by Dr. Matthew.

[63] Mr. L. S. Davis remembers collecting what he believes to be the type specimen of this species from the Rattlesnake gravels.

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1874—On the Great Lava Flood of the West, and on the Structure and Age of the Cascade Mountains. Am. Jour. Sci. (3), Vol. 7, pp. 167-180, 259-267.

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UNIVERSITY OF CALIFORNIA PUBLICATIONS

BULLETIN OF THE DEPARTMENT OF

GEOLOGY

Vol. 5, No. 12, pp. 207-215, Pls. 15-16 ANDREW C. LAWSON, Editor

QUATERNARY MYRIOPODS AND INSECTS OF CALIFORNIA.

BY

FORDYCE GRINNELL, Jr.

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INTRODUCTION.

In the recent work of exploration of the limestone caves of Shasta County, California, by Dr. J. C. Merriam, Dr. Wm. J. Sinclair and Mr. E. L. Furlong, the primary object was the investigation of the vertebrate faunas, but specimens of other forms, including a few myriopods, were obtained from both caves. During investigations in the asphalt beds near Los Angeles two beetles and several myriopods were found by Mr. Furlong, previous to December 1906, when the author joined Dr. Merriam and Mr. Furlong, and succeeded in making a small, but interesting collection of *Coleoptera* and *Myriopoda* from the vicinity of the bones in the asphalt. The author is greatly indebted to Dr. Merriam for the opportunity of studying this material, as well as the cave specimens from Shasta County.

Samwel Cave and Potter Creek Cave are located on the McCloud river in Shasta county. Samwel Cave[1] is fifteen miles above Baird. It lies in the belt of Carboniferous limestone exposed along the lower McCloud river. There are recognized in the deposits on the floor of this cave twenty species of vertebrates of which eight are extinct. The species from the different chambers are in some cases distinct, suggesting slightly different ages.

Potter Creek Cave[2] is situated on the McCloud river near Baird. It contains, so far as recognized, fifty-two species of vertebrates, of which twenty-one are extinct. Dr. Sinclair considers the fauna of Potter Creek Cave to represent the middle or later Quaternary; that of Samwel Cave is Quaternary, but later than that of Potter Creek Cave. The Myriopods from Potter Creek Cave surely indicate an earlier formation. Mr. Furlong has explored Samwel Cave and Dr. Sinclair has explored Potter Creek Cave, and the notes here given are taken from their papers. Dr. Merriam has compared the ages of the different caves of Shasta county, in a recent paper.[3]

[1] Furlong, E. L. The Exploration of Samwel Cave. American Journal of Science, XXII, 1906, pp. 235-247.

[2] Sinclair, Wm. J. The Exploration of the Potter Creek Cave. Univ. Calif. Publ. Amer. Arch. and Ethn., Vol. II, No. 1, 1904.

[3] Merriam, J. C. Recent Cave Explorations in California. American Anthropologist (n. s.), 8, No. 2, 1906.

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The asphalt beds[4] at Rosemary, near Los Angeles, cover a considerable area. Bones are scattered through the whole deposit, but in uneven numbers, and the beetles and myriopods were found in the neighborhood of the bones. Blake in his expedition through California in the early days noticed the bitumen lakes or tar springs, and similar ones are still found in the same region. The remains of the animals we find are of those which were entrapped in these tar springs. And if we note the preponderance of the family Tenebrionidae which come out from their hiding places in the evening to forage, their presence can readily be accounted for. One might expect to find carrion beetles, *Silphidae,* but when one reflects, it can readily be seen that if an animal has sunk out of sight, as it surely does in these tar springs, it is shut out from the air and no odor could attract carnivorous animals or insects. The plausible explanation is that insects just wandered or flew in by mistake; and the forms found certainly bear out this conclusion. The age of these beds is Quaternary. The great resemblance of the insects to those now living, in most cases amounting to identity, shows that it takes a long time to effect a change in the Coleoptera.

The writer's thanks are due Dr. F. E. Blaisdell and Dr. E. C. Van Dyke of San Francisco for assistance in the identification of the Coleoptera.

All of the drawings were executed by Miss Julia D. E. Wright of Palo Alto.

MYRIOPODA.

JULUS OCCIDENTALIS, n. sp.

Pl. 15, figs. 9 and 11.

Type specimens Nos. 10005 and 10006, Univ. Calif. Col. Invert. Palae. Samwel Cave, Shasta Co., Calif.

There are two fairly complete remains of this myriopod, besides some remains and fragments of others on a larger block. Both are coiled, one completely. The segmentation is very plain, and fairly constant in width; the intersegmental ridge is very pronounced, and high. The ventral furrow is comparatively

[4] Merriam, J. C. Recent Discoveries of Quaternary Mammals in Southern California. Science (n. s.), Vol. XXIV, pp. 248-250, 1906.

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large and deep, at least in one specimen, the stalagmitic covering obscures it somewhat.

This is smaller and more slender than any form heretofore known in California; the wide and deep ventral furrow is also a striking feature. It has some resemblance to *Julus antiquus* Heyden.

Length	86-109 mm.
Width	6
Width of segments	1.5

JULUS CAVICOLA, n. sp.

Pl. 15, figs. 1, 5, 10, and 12.

Type specimen No. 10007, Univ. Calif. Col. Invert. Palae. Potter Creek Cave, Shasta Co., Calif.

There are three separate parts of this myriopod, besides another buried in the block in the stalagmitic covering, and several other smaller pieces and segments. This species is quite different from the Samwel Cave species in several particulars. The ventral furrow is very much reduced in size and hardly noticeable—about 9 m.m. wide on an average. The segments are not so arched or the intersegmental ridge so protruding and very inconspicuous.

Length	15-20 mm.
Width	5.5-6
Width of segments	1

SPIROBOLUS AUSTRALIS, n. sp.

Pl. 15, figs. 13 and 14.

Type specimens Nos. 10008 and 10009, Univ. Calif. Col. Invert. Palae. Asphalt beds at Rosemary, near Los Angeles.

There is one well preserved fragment embedded in a lump of asphalt, besides a few scattering, isolated segments. This species bears a resemblance to *Spirobolus hebes* Bollman, from Southern California. In *S. australis* the middle of each segment is marked by a well defined furrow. The surface is smooth and shining generally, but in a few places it is very finely punctate. No ventral furrow or a very slight one. The specimen number 10009 I place here under this species as the probable early stage.

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It was found in the same place, and bears characteristics that would mark it as an early stage. It is 5.5 m.m. long, 2.5 m.m. wide, segments 1 m.m. wide. It is light brown in color, with a darker shade along the median sulcus. The species is very close to the living form.

Length of fragment	13 mm.
Width	10
Width of segments	3.75

COLEOPTERA.

PLATYNUS conf. FUNEBRIS LeConte.

Specimen No. 10010, Univ. Calif. Col. Invert. Palae. Asphalt beds at Rosemary, near Los Angeles.

A single elytron is present in the collection, and is probably referable to the common species, *P. funebris* Lec. This genus is well represented on the West Coast at the present time by common and closely allied species.

AMARA INSIGNIS Dej.

Pl. 16, fig. 17.

Specimen No. 10011, Univ. Calif. Col. Invert. Palae. Asphalt beds at Rosemary, near Los Angeles.

There are two well preserved and perfect elytra in the collection, agreeing exactly with living forms; belonging to a group, well represented, and common in California.

PTEROSTICHUS, sp. indet.

Specimen No. 10012, Univ. Calif. Col. Invert. Palae. Asphalt beds at Rosemary, near Los Angeles.

There are several elytra of this common but difficult genus, which are hardly determinable with our present knowledge.

CALOSOMA SEMILAEVE LeConte.

Pl. 16, fig. 26.

Specimen No. 10013, Univ. Calif. Col. Invert. Palae. Asphalt beds at Rosemary, near Los Angeles.

A beautifully preserved elytron of this characteristic and common Californian species enables us to leave no doubt as to the determination of this species.

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DYTISCUS MARGINICOLLIS LeConte.

Pl. 15, fig. 6.

Specimen No. 10014, Univ. Calif. Col. Invert. Palae. Asphalt beds at Rosemary, neat Los Angeles.

Two elytra of this species are fairly well preserved, but are crushed and flattened, so that the determination was at first difficult. This is one of the water beetles, which are found in the vicinity of streams and ponds throughout our region. They are strong flyers and frequently come to electric lights in the city. It can readily be imagined that this specimen which has been preserved to us was flying over the country in search of a pool or stream, and mistook the tar spring for a pool of fresh water.

CONIONTIS ROBUSTA Horn.

Pl. 16, fig. 27.

Specimen No. 10015, Univ. Calif. Col. Invert. Palae. Asphalt beds at Rosemary, near Los Angeles.

One elytron half buried in a hard lump of asphalt, but the characters of the above species seem unmistakable. The species of this genus are rather numerous in some parts of Southern California. They hide under boards and in the midst of rubbish and only come out to forage during the twilight and even into the night, so from this it can be readily seen how they came to be entrapped in the tar springs.

CONIONTIS ABDOMINALIS LeConte.

Specimen No. 10016, Univ. Calif. Col. Invert. Palae. Asphalt beds at Rosemary, near Los Angeles.

Two fairly well preserved specimens—with the head. The sculpture and striation are practically the same as in the living forms.

CONIONTIS PUNCTICOLLIS LeConte.

Specimen No. 10017, Univ. Calif. Col. Invert. Palae. Asphalt beds at Rosemary, near Los Angeles.

A portion of an elytron in fairly good preservation, showing the smooth, shining, lightly punctured and striated surface.

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CONIONTIS ELLIPTICA Casey.

Specimen No. 10018, Univ. Calif. Col. Invert. Palae. Asphalt beds at Rosemary, near Los Angeles.

The thorax and elytra of this species are present in recognizable condition. *Elliptica* and *robusta* are very closely related and some put them together. I was advised to do this, but on comparing the two I find sufficient difference to separate them. This form is more elongate; flatter; and the punctation and striation not so evident.

ELEODES ACUTICAUDA LeConte.

Pl. 15, fig. 7; Pl. 16, figs. 16, 18, and 21.

Specimens No. 10019, *a*, *b*, *c*. *d*, Univ. Calif. Col. Invert. Palae. Asphalt beds at Rosemary, near Los Angeles.

These all belong to the typical form of this species. There is some variation, but there is a greater variation in the living forms. The species of this genus like that of *Coniontis* hide in dark places, under boards, in rubbish and even in squirrel holes during the daytime, and come out to forage in the evening after sunset. So their presence in the tar springs can be easily accounted for on the assumption that they made a misstep.

ELEODES ACUTICAUDA LeConte.

FORMA PUNCTATA.

Pl. 15, fig. 2; Pl. 16, fig. 15.

Specimen No. 10020, *a*, *b*, Univ. Calif. Col. Invert. Palae. Asphalt beds at Rosemary, near Los Angeles.

This very punctate form is easily recognized and the specimens are in a fair state of preservation.

ELEODES BEHRII, n. sp.

Pl. 15, figs. 3 and 4.

Type specimen No. 10023, Univ. Calif. Col. Invert. Palae. Asphalt beds at Rosemary, near Los Angeles.

A perfect specimen—with the exception of the missing head. Narrowly oval, slightly flattened dorsally, tapering and depressed

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caudal, quadrate. The surface somewhat shining; punctation exceedingly evident, the punctures deep and broad; elytra smooth and glabrous. The margins of the elytra slightly rimmed. The epipleurum very wide cephalad and tapering, gradually, caudad.

This interesting and distinct species is related to *E. caudata,* and *E. parvicollis,* but is separated from both by the very punctate elytra like *E. caudata;* smooth and glabrous; and especially by the very wide epipleuræ, which are extraordinary, and nothing approaching it in this respect. It was very puzzling and the inclination was to put it in a different family, but it is placed here provisionally at least.

Length of specimen	10 mm.
Width	4.5
Greatest width of epipleurum	2.5

Dedicated to the memory of the best of my teachers, Hans Hermann Behr.

ELEODES CONSOBRINA LeConte.

Pl. 16, fig. 20.

Specimen No. 10021, Univ. Calif. Col. Invert. Palae. Asphalt beds at Rosemary, near Los Angeles.

The abdomen and elytra are well preserved, and characteristic of this species. The punctation and striation are very distinct.

ELEODES LATICOLLIS LeConte.

FORMA MURICATA MINOR.

Pl. 15, fig. 8; Pl. 16, figs. 19, 23, and 25.

Specimen No. 10022, Univ. Calif. Col. Invert. Palae. Asphalt beds at Rosemary, near Los Angeles.

The specimens are well preserved and characteristic, but all belong to the small, muricate form. There is considerable variation in the specimens, but there is as much in the living forms; and although some are strikingly different from living forms, it would hardly be of value to give names to such a variable group. There is a specimen 13 mm. long and another 19 mm. long.

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ELEODES INTERMEDIA, n. sp.

Pl. 16, fig. 29.

Type specimen No. 10024, Univ. Calif. Col. Invert. Palae. Asphalt beds at Rosemary, near Los Angeles.

A complete abdomen and elytra are present, but more or less flattened. Broadly oval, flattened; quadrate cephalad, and sides parallel until near the caudal end when the elytra turn downwards and end in a comparatively sharp and inwardly curved point. Surface of elytra rather densely punctate, but not so punctate as in *E. behrii.* Striæ indistinct. The epipleurum, cephalad, measures 1.5 mm. in width, tapering gradually to the tip of the elytra. Epipleurum smooth, shining, not so punctate as the elytra.

This species is related to *E. parvicollis, E. caudata,* and *E. behrii,* but is distinguished by the very wide epipleurum, and the very punctate elytra, dorsally.

Length	12 mm.
Width	8.5

ELEODES ELONGATA, n. sp.

Pl. 16, fig. 30.

Type specimen No. 10025, Univ. Calif. Col. Invert. Palae. Asphalt beds at Rosemary, near Los Angeles.

Form very elongate; quadrate, convex, very much rounded; apex abruptly tapering, downwards, to an acute point. Surface smooth, glabrous, shining. The edges of the elytron, slightly keeled, projecting dorsad. There are a very few scattering, coarse punctures on the elytron.

There is a single, fairly well preserved elytron in a piece of asphalt which seems to differ from others by its more elongate form; glabrous and shining surface and sparsely punctured; the keeled and strikingly projecting edge of the elytron and the abruptly tapering apex. Dorsad the elytron is very obtuse, only very slightly tapered.

Length	21.5 mm.
Width	9

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EXPLANATION OF PLATE 15.

Figs. 1, 5, 10, 12. *Julus cavicola,* n. sp. Type from Potter Creek Cave.

Fig. 2. *Eleodes acuticauda (forma punctata)* LeConte. From Rosemary, near Los Angeles.

Figs. 3 and 4. *Eleodes behrii,* n. sp. Type specimen from Rosemary, near Los Angeles.

Fig. 6. *Dytiscus marginicollis* LeConte. From Rosemary, near Los Angeles.

Fig. 7. *Eleodes acuticauda (forma muricata minor)* LeConte. From Rosemary, near Los Angeles.

Fig. 8. *Eleodes laticollis* LeConte. From Rosemary, near Los Angeles.

Figs. 9 and 11. *Julus occidentalis,* n. sp. Type specimen from Samwel Cave.

Figs. 13 and 14. *Spirobolus australis,* n. sp. Type specimen from Rosemary, near Los Angeles.

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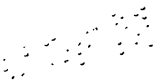

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EXPLANATION OF PLATE 16.

Fig. 15. *Eleodes acuticauda (forma punctata)* LeConte. From Rosemary, near Los Angeles.

Figs. 16, 18, and 21. *Eleodes acuticauda* LeConte. From Rosemary, near Los Angeles.

Fig. 17. *Amara insignis* Dej. From Rosemary, near Los Angeles.

Figs. 19, 23, and 25. *Eleodes laticollis (forma muricata minor)* LeConte. From Rosemary, near Los Angeles.

Fig. 20. *Eleodes consobrina* LeConte. From Rosemary, near Los Angeles.

Fig. 24. *Coniontis elliptica* Casey. From Rosemary, near Los Angeles.

Fig. 26. *Calosoma semilaeve* LeConte. From Rosemary, near Los Angeles.

Fig. 27. *Coniontis robusta* Horn. From Rosemary, near Los Angeles.

Figs. 22 and 28. *Eleodes acuticauda* LeConte. From Rosemary, near Los Angeles.

Fig. 29. *Eleodes intermedia*, n. sp. From Rosemary, near Los Angeles.

Fig. 30. *Eleodes elongata*, n. sp. Type specimen from Rosemary, near Los Angeles.

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UNIVERSITY OF CALIFORNIA PUBLICATIONS

BULLETIN OF THE DEPARTMENT OF

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Vol. 5, No. 13, pp. 217-223, Pls. 17-18 ANDREW C. LAWSON, Editor

NOTES ON THE OSTEOLOGY OF THE THALATTOSAURIAN GENUS NECTOSAURUS.

BY

JOHN C. MERRIAM.

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INTRODUCTION.

During the summer of 1906 an expedition from the University of California visited the exposures of the Hosselkus Limestone in the Upper Triassic of Shasta County, California, with the purpose of making a special search for material representing the recently described thalattosaurian reptiles.[1] A few scattered bones of *Nectosaurus* were found in the basal layer of the upper or massive, grey horizon of the limestone near Brushy Slope camp on the western side of Brock Mountain, but the greater part of the material representing this genus was obtained in a narrow belt of limestone near the North Fork of Squaw Creek. In the North Fork exposures numerous scattered bones including *Nectosaurus*, *Shastasaurus*, and *Thalattosaurus* were obtained in a stratum evidently representing the top of the blue, shaly lower division of the Hosselkus Limestone, or the base of the massive, grey

[1] The Thalattosauria. Merriam, J. C., Mem. Calif. Acad., Vol. 5, No. 1.

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upper division. The limestone of this horizon is composed in a large part of broken shell fragments, and the bones are almost invariably isolated, indicating that the deposit was formed in rather shallow water, where the skeletons were tossed about by the waves. At this horizon the remains are principally those of *Nectosaurus, Thalattosaurus* bones being comparatively rare.

SKULL AND DENTITION.

There are in the collections several specimens representing the upper and lower jaws, and clearly showing the characters of the dentition. Specimen 10753 (pl. 17, fig. 1) shows nearly all of the maxillary excepting the anterior end. The posterior portion of the bone exhibits the area of contact with the lachrymal or prefrontal, and the long posterior extension which was in contact with the jugal. The teeth in this jaw are slender conical, with the crowns showing a slight lateral compression. The structure of this jaw differs considerably from that of a specimen (No. 10620) previously referred to tentatively as the maxillary of *Nectosaurus.*[2] The characters of specimen No. 10753 seem, however, to be pretty certainly those of the maxillary, and approach those of the better known *Thalattosaurus perrini.* Specimen 10620 may therefore represent one of the other dentigerous elements, though its reference is still uncertain.

A small fragment consisting of two closely united dentigerous bones (No. 10778) may represent the anterior ends of the premaxillaries or the anterior portion of the prevomers. A single perfect tooth near the anterior end of this fragment is short, thick, conical, and somewhat more acuminate than the most anterior teeth of the prevomers in *Thalattosaurus,* but much less slender than the anterior teeth of the jaws.

A number of small specimens representing the lower jaw with dentition show the teeth to be conical but apparently not as slender as in the maxillary. The crowns also show more lateral compression than was suspected in the study of the type specimen of *Nectosaurus.*

In specimen 10797 the greater part of a mandible is preserved, but the coronoid element and the dentition are unfortunately

[2] Merriam, J. C., Op. cit. pl. 5, fig. 6.

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absent. The length of the jaw from the anterior end of the dentary to the middle of the cotylus is 85 mm. The height of the mandible near the middle is a little less than 13 mm.

The pterygoid is represented by several specimens which have been so weathered as to show the lateral and inferior aspects of this bone. A lateral view of No. 10770 shows the high superior wing, which is about as prominent as in *Thalattosaurus,* and is similarly sculptured. In specimen 10817 (pl. 17, fig. 3) the palatal side of a very small individual is exposed. It is not essentially different from that of the pterygoid of the type specimen of *Thalattosaurus.* The dentigerous area shows three or more longitudinal rows of distinct pits in a few of which the broken fangs of the teeth remain. The edentulous area next the base of the superior wing has about the same form as in *Thalattosaurus alexandrae.*

Another and somewhat larger pterygoid, No. 10626 (pl. 17, fig. 2) may represent *Nectosaurus* or one of the smaller species of *Thalattosaurus.* The well exposed dentigerous area shows not less than three longitudinal rows of teeth, of which one has contained at least seven teeth. The crowns are all circular in cross-section, and the two or three which are complete are slender acuminate. The bases of several of the larger teeth are distinctly seen to be anchylosed to the bone.

ARCHES AND LIMBS.

The scapula of *Nectosaurus* (pl. 18, fig. 2), which has not been known before, has a form closely resembling that of *Thalattosaurus shastensis,* from which it differs mainly in its somewhat narrower distal blade.

A number of small, slender limb bones, principally representing the propodial segments of the limbs, have been found with other material referred to *Nectosaurus.* Several of these are nearly complete and show the shaft to be more slender than that of *Thalattosaurus shastensis.* The middle region of the shaft is nearly round in cross-section. The proximal end is slightly expanded. The distal extremity is considerably broadened and flattened (No. 10800, pl. 18, fig. 1). It is uncertain whether these elements represent the humerus or the femur, but in one or two

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cases the suggestion of foramina on the expanded distal end may indicate that these particular specimens are humeri.

In the same deposits with the larger limb elements are a number of smaller and more slender bones with less expanded ends. Though it is not possible to distinguish these certainly from those determined as propodials, it is probable that some of them represent epipodials or podials (pl. 17, figs. 4 and 5).

VERTEBRAE AND RIBS.

Numerous isolated vertebrae were found in the lower portion of the upper, massive division of the Hosselkus Limestone on Brock mountain, and in the limestones along the North Fork of Squaw Creek. The vertebrae are always scattered, and as yet no connected series representing these forms is known. The upper arches are closely connected with the centra in nearly all cases. Only in a few instances can the line of division between them be distinctly seen, and in most instances the connection is so intimate that even the suture is almost obliterated.

The centra are all biconcave, but the terminal faces are in general not deeply cupped. In a single instance a somewhat broken centrum (No. 10806) was found which is gently concave toward the periphery of the faces, but is much more sharply excavated near the middle. The centrum is also relatively short anteroposteriorly, so that the anterior and posterior concave faces almost meet in the middle. This specimen possibly represents a middle or a distal caudal centrum of *Nectosaurus*, or may represent an ichthyosaurian genus.

The centra are about as long as high in most cases. There is evidently some variation in different regions of the column, the length being in some instances slightly greater and in others somewhat less than the height, as is indicated by the measurements below.

	Length of centrum	Height of centrum	Height of Neural arch	Number of lateral apophyses
No. 10774 (dorsal?)	6 m.m.	5.3	11.5	2
No. 10627 (dorsal?)	6	6.5	.....	1, large
No. 10787 (dorsal?)	7.7	8.4	*a* 16.5	2 ?
No. 10779 (caudal)	5.2	5.2	13 slender	none
No. 10806	*a* 4.5	*a* 7	.....	.....

a, approximate.

No. 10806, possibly ichthyosaurian.

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The upper arches are considerably higher than the centra. In specimen 10774 (pl. 18, fig. 6), showing a double headed articulation with the rib, the spine is considerably flattened laterally, but is not particularly broad anteroposteriorly. In specimen 10779 (pl. 18, fig. 5) with no lateral apophyses, and evidently representing the caudal region, the spine is high and very slender with almost no lateral compression. Zygapophyses are distinctly shown even in the caudal vertebra (No. 10779), where they are very prominent. In most cases the vertical element in the position of the faces of articulation seems to be much greater than the horizontal. In one specimen (No. 10787) the faces seem to have come nearer to a horizontal plane, but they are somewhat damaged and it is not possible to be absolutely certain of this determination.

The lateral apophyses in articulation with the ribs are single on some specimens and widely divided on others. On specimen No. 10627 (pl. 18, fig. 4) the large and prominent apophysis is nearly as high as the centrum, but is clearly undivided on its finely exposed articular face. A nearly obliterated line of division between the upper arch and the centrum appears to cross the apophysis some distance above the middle, as in the anterior vertebrae of *Thalattosaurus*. In specimen No. 10774 there are two distinctly separated lateral apophyses. The parapophysis is low down on the anterior margin of the centrum. The articulation of the tubercle seems to be about equally divided between the upper margin of the centrum and the base of the lower arch.

On specimen No. 10787 there is evidence of separation of a distinct inferior apophysis. The zygapophyseal faces are relatively large on this specimen and have a more nearly horizontal position than in most of the others. In this specimen the neural arch resembles considerably the anterior dorsal or cervical arch described with the type specimen of *Thalattosaurus shastensis*. If this is the case the double rib articulation might be suspected to occur in the anterior region of the vertebral column, the undivided apophyses being present on middle or posterior dorsals.

The structure of the vertebrae here referred to *Nectosaurus* is in general much like that in the genus *Thalattosaurus*. The two genera resemble each other and differ from the Ichthyosauria in the relatively slight degree of biconcavity of the centra, and in

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the tendency of the neural arches to fuse with the centra. A double articulation of the ribs such as is seen in some of the *Nectosaurus* specimens has not thus far been known in *Thalattosaurus*. The rib articulation is however only slightly different in the two genera. Though there is no absolute division of the lateral apophyses of the vertebrae in *Thalattosaurus*, the apophyses of the dorsal vertebrae are known to be strongly constricted. The position of the rib head with reference to the centrum and the upper arch is the same in the two genera.

A number of ribs showing well preserved articular faces have been obtained and in nearly all of these the head and tubercle are distinctly separated by a deep notch (pl. 18, fig. 3).

CONCLUSIONS.

The characters of the elements of the skull and of the dentition of *Nectosaurus* are essentially of the thalattosaurian type. The nature of the attachment of the teeth is more clearly shown than it has been previously, and indicates that teeth may be set in deep, distinct pits without apparent anchylosis with the jaw, or their bases may be fused with the bone.

The limb elements obtained are all of a more elongated or more slender type than is seen in the typical *Thalattosaurus*. Those propodial elements which are well enough preserved to show the outlines of the bones are even more slender than the humerus of the small *T. shastensis*. Such material as is available seems to indicate that the epipodials and possibly the podials[3] were little more specialized than in typical shore forms. The suggestion made by the writer in a previous publication[4] that *Nectosaurus* may have been a shore dweller to a greater extent than *Thalattosaurus*, seems to be supported not only by the less distinctly specialized or adapted limbs, but also by the fact that the remains are most common in deposits containing considerable quantities of comminuted shells, which would naturally occur near the shore. The suggestion that *Nectosaurus* represents the shore-dwelling young of *Thalattosaurus* seems to be met by the fact

[3] The term *podials* as used here is intended to include metapodials and phalangeal elements.

[4] Merriam, J. C., Op. cit., Vol. 5, p. 23.

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that the dentition differs very considerably in the two forms. It should also be noted, that *Nectosaurus* is not uncommon in the deeper water deposits just above the base of the upper division of the Hosselkus Limestone, where *Thalattosaurus* has not yet been recognized.

The vertebrae and ribs agree in structure with what has previously been described for this genus and for *Thalattosaurus*, excepting that specimens have been obtained showing a distinct bicipital rib articulation in addition to those with but one articulation. The presumption is that the situation here is similar to that in some other rhynchocephalians, and in most Triassic ichthyosaurs, the anterior ribs being double-headed, while single articulation appears in the dorsal region.

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EXPLANATION OF PLATE 17.

Nectosaurus halius Merriam.

From the Upper Triassic of Shasta County, California.

Fig. 1. Left maxillary. No. 10753. × 2. Page 218.

Fig. 2. Pterygoid, inferior view. No. 10626. × 2. Page 219.

Fig. 3. Pterygoid, inferior view. No. 10817. × 4. Page 219.

Fig. 4. Epipodial? No. 10755. × 3. Page 220.

Fig. 5. Epipodial? and metapodials? No. 10783. × 2. Page 220.

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EXPLANATION OF PLATE 18.

Nectosaurus halius Merriam.

From the Upper Triassic of Shasta County, California.

Fig. 1. Propodial element. No. 10800. × 2. Page 219.

Fig. 2. Scapula. No. 10803. × 2. Page 219.

Fig. 3. Rib (anterior dorsal?). No. 10758. × 2. Page 222.

Fig. 4. Vertebra (middle or posterior dorsal?) posterior side of centrum. No. 10627. × 2. Page 221.

Fig. 5. Anterior caudal vertebra, side view. No. 10779. × 2. Page 221.

Fig. 6. Vertebra (dorsal?) side view. No. 10774. × 2. Page 221.

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UNIVERSITY OF CALIFORNIA PUBLICATIONS

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NOTES ON SOME CALIFORNIA MINERALS

BY

ARTHUR S. EAKLE.

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I.—Linarite, Caledonite, Brochantite, and Anglesite from the Cerro Gordo District, Inyo County.

Linarite.—The beautiful azure-blue linarite that was discovered some years ago in the Cerro Gordo mine of Inyo county occurs characteristically in diverging and radiating aggregates of thinly bladed crystals with their elongation parallel to the *b*-axis. The blades are in general not separable and show only a few imperfect dome faces. Good crystals, however, are to be found in the cavities of the white quartz and brown sulphate matrix, intimately associated with green caledonite and brochantite. A few of these crystals were measured for their forms, but a more complete description of the mineralogy of this district is reserved for a future report. The only previous measurements

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of linarite from this locality were made by Rogers (Mineralogical Notes, Amer. Journal Sci. 1901, (4), *12*, 42), and his crystals showed only a few forms.

In the orientation of Kokscharov, as given by Dana, the broader prominent plane, parallel to which most of the crystals are tabular, is taken as the base, whereas Goldschmidt in his "Winkeltabellen" reverses the crystals and makes the rear dome ($\bar{1}01$), the base. There appears to be no advantage in changing the orientation as given by Dana and it is therefore followed here. The crystals are very small, but show a good zone of orthodomes with minute faces on the edges formed by the domes and unit prism. A measurement of one of the best of the crystals, which appeared to be a simple crystal, showed by the symmetry that it was twinned on the orthopinacoid. Fig 1 (pl. 19) is an orthographic projection on the base of this twinned crystal with the lower faces shown in dotted lines, and fig. 2 is the clinographic drawing from this projection to illustrate the general habit and combination of forms.

Fifteen forms were found, of which three are new for linarite.

c	(001)	*o*	($\bar{2}03$)	*w*	(012)	*i*	($\bar{7}16$) new
a	(100)	*s*	($\bar{1}01$)	*r*	(011)	*k*	(211) new
m	(110)	*x*	($\bar{3}02$)	*q*	($\bar{1}12$)	*h*	(14.0.1) new
l	(210)	*u*	($\bar{2}01$)	*g*	($\bar{2}11$)		

Rogers gives (010) on his crystal, but the clinopinacoid was not observed by the writer.

A calculation of the elements for linarite based on the axial ratio $a:b:c = 1.716:1:0.8296$, $\beta = 77° 23'$ gives

$p_0 = 0.4834$	$p'_0 = 0.4954$	$e = 0.2184$
$q_0 = 0.8096$	$q'_0 = 0.8296$	$e' = 0.2239$

The readings on the separate faces are given in the following table, the faces underscored being in twinned position.

		Measured		Calculated	
		ϕ	ρ	ϕ	ρ
	001	90°00′	12°40′	90°00′	12°37½
c	$\underline{00\bar{1}}$	90 00	12 44		
a	100	90 00	90 00	90 00	90 00
	$\underline{\bar{1}00}$	90 00	90 00	90 00	90 00
	110	30 55	90 00	90 00	

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		Measured		Calculated	
		ϕ	ρ	ϕ	ρ
m	$\bar{1}10$	30 47	90 00		
	$1\bar{1}0$	31 06	90 00	30 50	90 00
	$\bar{1}\bar{1}0$	30 40	90 00		
l	$2\bar{1}0$	49 38	90 00	50 03	90 00
o	$\bar{2}03$	90 00	6 45	90 00	6 04
	$20\bar{3}$	90 00	6 28		
s	$10\bar{1}$	90 00	15 15	90 00	15 11
	$\bar{1}01$	90 00	15 10		
x	$\bar{3}02$	90 00	27 35	90 00	27 26
	$30\bar{2}$	90 00	27 45		
u	$\bar{2}01$	90 00	37 25	90 00	37 29
	$20\bar{1}$		37 30		
w	012	28 40	25 16		
	$0\bar{1}2$	28 34	25 06	28 22	25 14
	$01\bar{2}$	28 00	25 02		
r	011	15 41	40 43		
	$0\bar{1}1$	15 14	40 31	15 07	40 44
q	$\bar{1}12$	2 43	22 24	3 16	22 34
g	$\bar{2}11$	42 40	48 03	42 45	48 29
k	$21\bar{1}$	55 42	55 29	55 40	55 47
	$\bar{2}\bar{1}1$	55 34	55 33		
i	$\bar{7}16$	67 58	19 40	68 40	20 19
	$7\bar{1}6$	68 38	20 54		
h	$\bar{1}4.0.1$	81 08	90 00	81 19	90 00
	or				
	$\bar{4}1.0.3$			81 06	90 00

Of the new forms *k*, *i*, and *h*, the symbol for *k* is unquestionably correct; *i* shows a variation of several minutes in the two readings, but the symbol as given is believed to be the true one; *h* is such a steep dome that an error of a few minutes in the reading will change materially the symbol, so while the form occurs as a narrow dome and the reading was good the symbol is to be classed as doubtful. It corresponds closely to ($\bar{4}1.0.3$), but the simpler symbol ($\bar{1}4.0.1$) has been chosen.

Caledonite.—This mineral occurs in abundance with the linarite in bright crystals of a deep emerald green color. The crystals are very minute and are elongated parallel to the *a*-axis. Occasionally they are somewhat tabular parallel to the base or to the

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clinopinacoid, but in general the base and pinacoid are in about equal development. Most of the faces are brilliant and give good reflections, but the clinopinacoid is invariably striated parallel to the edge *bc*.

The habit and combination of forms of the stocky crystals is seen in plate 19, fig. 3.

The forms observed on the crystals were:

c (001)	*x* (201)	*f* (012)	*t* (221)	*o* (014) new
b (010)	*δ* (021)	*ψ* (013)	*r* (111)	*n* (203) new
m (110)	*e* (011)		*s* (223)	

In setting up the crystals for measurement the best results were obtained by assuming the position *a* as the pole face and zone *bc* as first meridian. The readings in this position are given in the columns ϕ' and ρ'. With *c* as the pole face the transposed angles corresponding to these readings are in columns ϕ'' and ρ'' obtained by means of the two formulae cos. $\rho'' =$ cos. ϕ' sin. ρ' and cot. $\phi'' =$ sin. ϕ' tan. ρ'.

		Measured				Calculated	
		ϕ'	ρ'	ϕ''	ρ''	ϕ	ρ
c	001	0°00′	90°00′	0°00′	0°00′	0°00′	0°00
b	010	90 00	90 00	0 00	90 00	0 00	90 00
m	110	89 57	42 30	47 30	90 00	47 27	90 00
o	014	19 34	90 00	0 00	19 34	0 00	19 23
ψ	013	25 14	90 00	0 00	25 14	0 00	25 07
f	012	35 15	90 00	0 00	35 15	0 00	35 07
e	011	54 41	90 00	0 00	54 41	0 00	54 35
δ	021	70 41	90 00	0 00	70 41	0 00	70 26
x	201	0 00	18 16	90 00	71 44	90 00	71 55
n	203	0 00	44 28	90 00	45 32	90 00	45 37
t	221	70 29	44 16	47 26	76 31	47 27	76 29
r	111	54 32	48 25	47 27	64 17	47 27	64 19
s	223	43 07	53 19	47 27	54 10	47 27	54 12

The new form *o* (014) occurs as a narrow face lying on both sides of the base and four faces of it were observed. The dome *n* (203) was observed but once as a very narrow face truncating the edge of (223) ($2\bar{2}3$).

Brochantite.—In measuring what were supposed to be caledonite crystals, it became apparent from the angles that some of the crystals were brochantite. The two minerals are intimately associated, and have the same emerald green color. The crystals are so minute that they had to be handled with a magnifying

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lens, and it was only by the measurements that the writer could in most cases tell whether he had brochantite or caledonite set up. The habit of the brochantite crystals is in general different from that of the caledonite. The crystals are characteristically in thin plates, tabular to (010) and elongated prismatic and in the direction of the *a*-axis. Occasional (010) is narrower with a corresponding increase in the width of the prismatic faces, thus giving a more stocky appearance to the crystals. The general habit and common combination of forms is seen in plate 19, fig. 4.

The forms occurring on the crystals are:

c	(001)	*e*	(012)
b	(010)	*i*	(011)
m	(110)	*v*	(101)
r	(120)	*g*	(041) new

		Measured		Calculated	
		ϕ	ρ	ϕ	ρ
c	001	0°00′	0°00′	0°00′	0°00′
b	010	0 00	90 00	0 00	90 00
m	110	52 05	90 00	52 07	90 00
r	120	32 40	90 00	32 44	90 00
e	012	0 00	13 37	0 00	13 47
i	011	0 00	25 50	0 00	26 08
g	041	0 00	62 35	0 00	63 00
v	101	90 00	32 12	90 00	32 14

The base was observed on one crystal only and as a mere line face. One face of *e* is the common terminating form, yet on the crystal having the base both faces occurred in one end. The new form *g* occurred as a narrow face between *b* and *e*, but was found only once. The prism *m* shows the best faces on the crystals, and gave the best reflections. The remaining prism *r* is also usually good, but sometimes rounds by striatures into *b*. The crystals also showed a pyramid, and rough measurements indicated that it was the unit pyramid (111), but no good reflections could be obtained from it. The pinacoid *b* is striated vertically and presents one good face, giving a fair signal, while the opposite side is rounded and striated, and gives only a train of signals. There is some doubt regarding the system of crystalization of brochantite. The crystals from this locality possess at least two planes of symmetry, but the striking difference in the development of the two brachy-pinacoidal sides suggest that they may be hemimorphic-orthorhombic.

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This constitutes the first notice of brochantite from this locality.

Anglesite.—Specimens of galena with small colorless anglesite crystals were lately collected at the Cerro Gordo mine by Mr. John Reid, and given to this department. The anglesite crystals are somewhat flattened parallel to the base and elongated in the direction of the *a*-axis. They are terminated on one end by the sharp pyramid (122) and joined to the matrix by the other end. See plate 20, fig. 5.

c (001) *m* (110) *z* (111) *o* (011)
a (100) *l* (104) *y* (122)

		Measured		Calculated	
		ϕ	ρ	ϕ	ρ
c	001	0°00′	0°00′	0°00′	0°00′
a	100	90 00	90 00	90 00	90 00
m	110	52 00	90 00	51 51	90 00
l	104	90 00	22 20	90 00	22 19
o	011	0 00	52 11	0 00	52 12
z	111	51 51	64 14	51 51	64 24
y	122	32 28	56 49	32 28	56 49

The base is striated parallel to its length, but all the other faces are very bright and perfect.

II.—Celestite from San Bernardino County.

When colemanite was discovered in Southern California it was observed that celestite was its associate, occurring as good crystals in the geodal masses of colemanite. As the forms of these crystals have not been stated, the writer measured a few of them.

The celestite from the Calico district is generally in broad plates, tabular to the base and grown together in parallel positions. The habit of these crystals is seen in plate 20, fig. 6.

The observed forms were:

c (001) *d* (102) *o* (011)
m (110) *l* (104)

A strikingly different habit for celestite is seen in a specimen of colemanite from Death valley. The crystals appear like long slender prisms terminated on one end by a sharp pyramid and attached by the other end to the matrix. They are, however, elongated in the direction of the *a*-axis, and consist principally of

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the brachydome *o* (011) and the brachypyramid *y* (122). The other forms are all very subordinate and sometimes lacking. The general habit is seen in plate 20, fig. 7.

The forms identified on these crystals were.

c (001) *d* (102) *o* (011) *P* (067) new
m (110) *l* (104) *y* (122)

		Measured		Calculated	
		ϕ	ρ	ϕ	ρ
c	001	0°00′	0°00′	0°00′	0°00′
m	110	90 00	52 01	90 00	52 00
d	102	90 00	39 11	90 00	39 23
l	104	90 00	22 22	90 00	22 19
o	011	0 00	52 01	0 00	52 04
P	067	0 00	47 31	0 00	47 35
y	122	32 35	56 43	32 37	56 43

The new form *P* (067) occurred on both sides of the base as long narrow faces and the reflections were good.

III.—Stibnite from Hollister, San Benito County.

California has long been known for her deposits of stibnite, and many fine specimens have been obtained from the various mines. Most of the prisms, however, are deeply furrowed, bent, twisted, and without terminating faces; consequently good measurements of them are seldom possible. In looking over a lot of the material from the State, some specimens coming from the vicinity of Hollister were seen to consist of isolated crystals with good terminal faces, and a few of these were measured. The habit and forms are seen in plate 20, fig. 8.

The observed forms were:

b (010) *n* (210) *s* (113)
m (110) *h* (310) *y* (102) new
q (130) *k* (430) δ (4.5.12)

		Measured		Calculated	
		ϕ	ρ	ϕ	ρ
b	010	0°00′	90°00′	0°00′	90°00′
q	130	18 20	90 00	18 34	90 00
m	110	45 11	90 00	45 13	90 00
k	430	53 15	90 00	53 20	90 00
n	210	64 12	90 00	63 36	90 00
h	310	72 00	90 00	71 41	90 00
y	102	90 00	27 20	90 00	27 09
s	113	45 22	25 44	45 13	25 43
δ	4.5.12	39 08	28 05	38 52	28 34

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The new form (102) occurs on several of the crystals in small triangular faces. Readings were also obtained for other prisms, but owing to the striated condition of the prismatic zone they were not definitely established as forms.

IV.—ENARGITE FROM ALPINE COUNTY.

Crystals of enargite from the Morning Star mine were originally described by Silliman,[1] but he gave only the unit prism and the three pinacoids as present. In looking over some specimens of pyrite containing crystals of enargite from this mine it was seen that more forms existed than those given by him. The crystals are prismatic in habit and terminated on one end by a broad basal plane and attached to the matrix at the other. The habit and combination are seen in plate 20, fig. 9.

The forms observed were:

c (001) *f* (250) new *k* (101)
a (100) *l* (130)
b (010)
m (110)

		Measured		Calculated	
		ϕ	ρ	ϕ	ρ
c	001	0°00′	0°00′	0°00′	0°00′
a	100	90 00	90 05	90 00	90 00
b	010	0 00	90 05	0 00	90 00
m	110	48 46	90 05	48 56	90 00
f	250	24 43	90 05	24 40	90 00
l	130	20 42	90 05	20 56	90 00
k	101	90 00	44 00	43 20	90 00

The dome *k* (101) was very small and only an approximate reading could be obtained, but it was sufficient to establish the presence of the form.

The new prism *f* (250) was present on one crystal as a narrow face and the reading was good. A pyramid was also present but the face was dull and its symbol could not be definitely determined.

V.—ARCANITE FROM ORANGE COUNTY.

A few small yellowish plates of a mineral which were sent to the writer by Mr. Norman E. Smith for identification proved to be the natural potassium sulphate. They came from Tunnel

[1] American Journal of Science, 1873 (3), *5*, 384.

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No. 1 of the Santa Ana Tin Mining Company in Trabuco Cañon, Orange county, and were found about two hundred and fifty feet below the surface in an old Oregon pine tie which is partly submerged six months of the year. The tunnel is in black slate which carries some sulphide and the walls of the mine are coated with minute crystals and incrustations of sulphates and carbonates. The potassium sulphate has not hitherto been recognized as a mineral species, so this occurrence classes it as a new mineral. The name Arcanite has however been applied to the potassium sulphate and artificial crystals have been measured.

The crystals are thin plates tabular to *c* and are pseudo-hexagonal by twinning on the unit prism. Plate 20, fig. 10 shows the appearance.

The forms observed were:

c (001)	*s* (112)
o (111)	*e* (102)

	Measured	Calculated
(001) : (111)	— 55°48′	56°21′
(111) : (11$\bar{1}$)	— 67 20	67 18
(111) : (1$\bar{1}$1)	— 48 37	48 52
(001) : (112)	— 36 12	36 54
(111) : (112)	— 19 30	19 27
(111) : ($\bar{1}\bar{1}$0)	— 48 50	

The faces were in general dull, and *c* gave only a bright spot of light, so that accurate measurements could not be made from this face. The *o* faces were better and gave good reflection. The *s* faces were always mere lines. Besides these faces, the dome, probably *e* (102), was present, but it was so rough that only an approximate measurement could be made.

Transmitted, May, 1908.
Date of Issue, November 28, 1908.

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EXPLANATION OF PLATE 19.

Fig. 1.—Linarite. Twinned on orthopinacoid. Orthographic projection on base. Cerro Gordo.

Fig. 2.—The same. Clinographic drawing.

Fig. 3.—Caledonite. Cerro Gordo.

Fig. 4.—Brochantite. Cerro Gordo.

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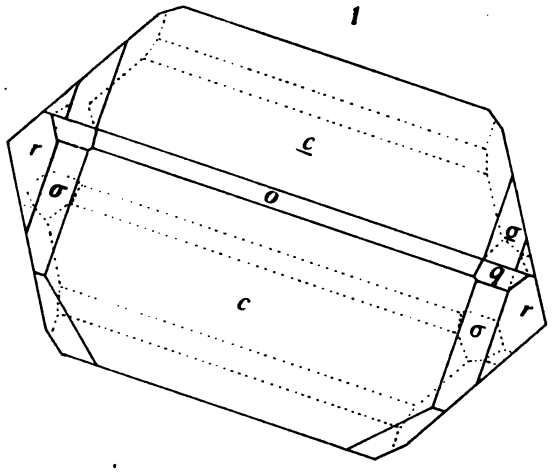

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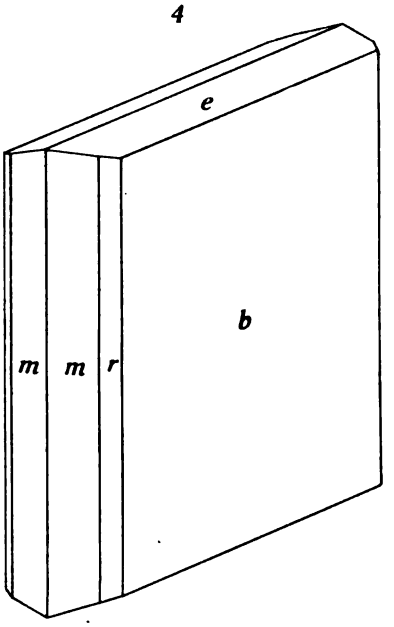

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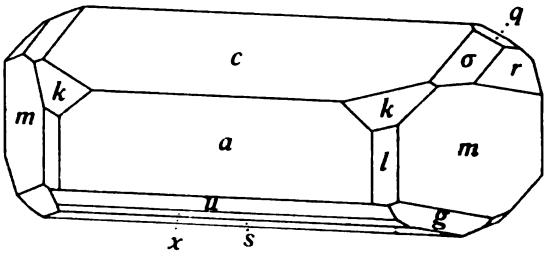

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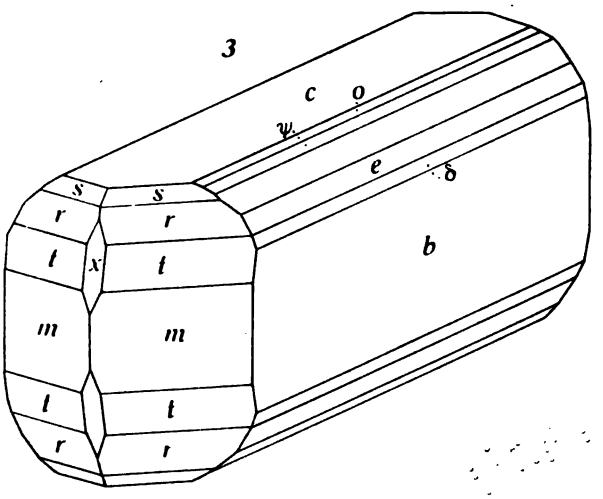

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EXPLANATION OF PLATE 20.

Fig. 5.—Anglesite. Cerro Gordo.

Fig. 6.—Celestite. Calico district.

Fig. 7.—Celestite. Death Valley.

Fig. 8.—Stibnite. Hollister.

Fig. 9.—Enargite. Alpine County.

Fig. 10.—Arcanite. Orange County.

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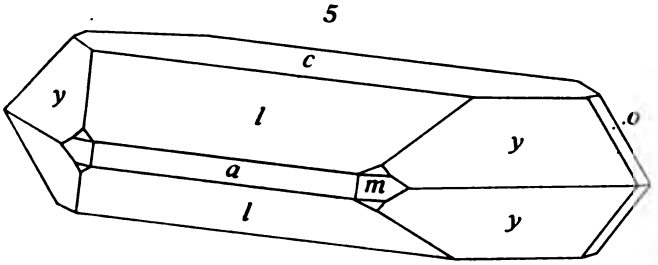

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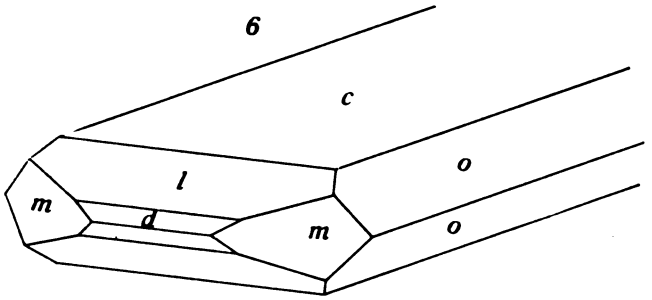

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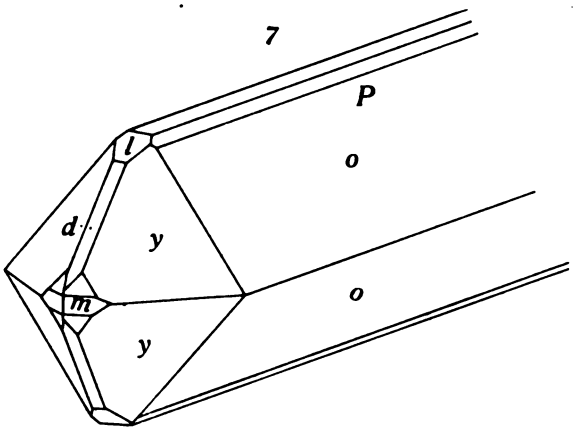

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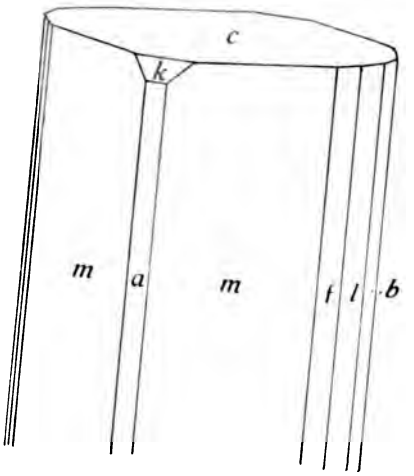

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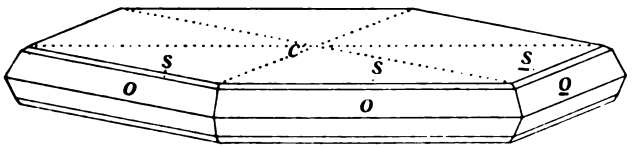

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UNIVERSITY OF CALIFORNIA PUBLICATIONS

BULLETIN OF THE DEPARTMENT OF

GEOLOGY

Vol. 5, No. 15, pp. 235-242 ANDREW C. LAWSON, Editor

NOTES ON A COLLECTION OF FOSSIL MAMMALS FROM VIRGIN VALLEY, NEVADA.

BY

JAMES WILLIAMS GIDLEY.

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Through the kindness of Dr. John C. Merriam of the University of California, I have recently had placed in my hands for study and determination an interesting little collection of fossils from Virgin Valley, Nevada. The material consists principally of fossil horse remains representing at least two genera and five species of the Equidae. One species referable to a genus of the Cervidae is also represented in the lot. Some of the species are probably new, but the material is too fragmentary for little more than generic determination, and the specimens are not sufficiently characteristic to warrant burdening literature with added names not well established by distinctive specific characters.

The object of the present paper, therefore, is to report the forms represented from this locality and to describe the more important specimens of the collection with the primary object of

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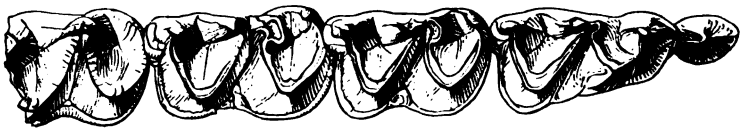
throwing some light on the age of the Virgin Valley beds. These specimens are listed and described below.

HYPOHIPPUS ? EQUINUS (Scott).

Fig. 1.

A portion of a right lower jaw, containing the milk molars and the first permanent molar (no. 10665, Univ. Calif. Col. Vert. Palae.), may be referred provisionally to *Hypohippus equinus*,



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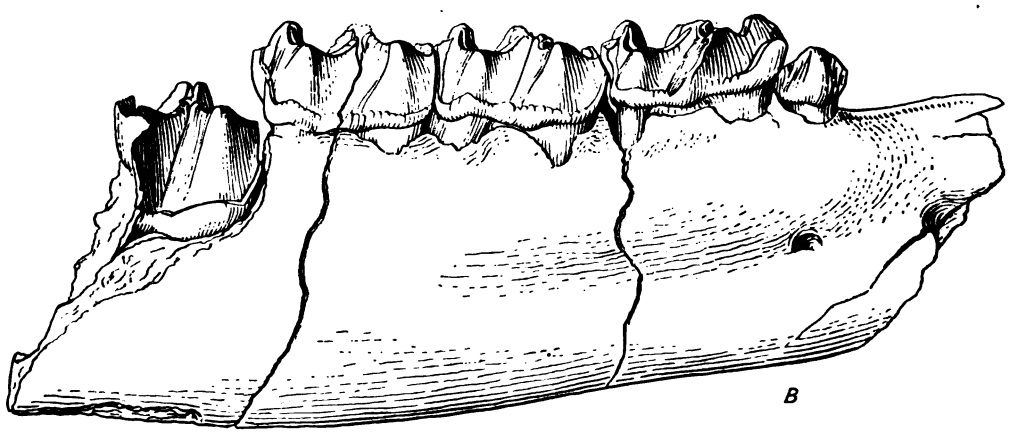

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Fig. 1.—*Hypohippus? equinus* (Scott). Portion of a right lower jaw with milk molars and first permanent molar. A, occlusal view; B, lateral view. No. 10665, natural size.

which it about equals in size. The teeth, however, as indicated by the single permanent molar preserved, are apparently somewhat higher crowned than those of the type of the Deep River species. But this apparent difference may be due in part to the considerable degree of wear in the latter, while, in the specimen from Virgin Valley, m_1 although completely formed is entirely

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unworn. A second important difference is the relatively greater depth of the lower jaw, which further suggests that this specimen may after all represent a new species.

The lower milk-dentition of species of *Hypohippus* has not hitherto been known, hence the deciduous teeth of the present species can be compared only with the permanent series and with those of other genera where they are known. The lower milk molars of the present species present in general the characters distinctive of the genus. As in other species of horses, the crowns are relatively lower and narrower transversely than those of the permanent series.

The more important characters which distinguish the milk-molars of *Hypohippus* from those of *Mesohippus* are as follows: They have a heavier and better developed external basal cingulum, the two outer cusps, pr^d and hy^d, are fuller and wider transversely, and the teeth are more specialized in general than in species of *Mesohippus.* Advanced development in *Hypohippus* is especially marked in dp_2 in which the anterior external cusp has attained a completely crescentic form similar to that of the posterior cusp, while in *Mesohippus* this tooth has but one crescent, or V, the posterior one. In this respect dp_2 of *Hypohippus* is more highly specialized than p_2 of the permanent series of either *Mesohippus* or *Hypohippus* and resembles the p_2 of *Parahippus.* The metaconid-metastylid column is broader anteroposteriorly than in the permanent molariform teeth of the genus, and these cusps are slightly but distinctly separated at the summit of the column.

Compared with the corresponding tooth, dp_2, associated with the type of *Parahippus cognatus,* that of *Hypohippus* presents the following characteristic differences: (1) The outer basal cingulum is much better developed and is continuous, while it is entirely interrupted on the external walls of the protoconid and hypoconid in *P. cognatus;* (2) the summits of the outer cusps, hy^d and pr^d, are situated relatively nearer the outer side of the crown, giving a less abrupt slope to the outer walls of the internal valleys; (3) the cusps of the inner row are less well developed throughout; and (4) the metastylid is much less prominent and not separated from the metaconid except slightly at the extreme

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summit. In *P. cognatus* it is completely separated by a deep groove extending to the base of the crown.

MEASUREMENTS.

Diameters of m_1, anteropost. 22 mm., transv. 17 mm.
Diameters of dp_1, anteropost. 9.5 mm., transv. 6.5 mm.
Diameters of dp_2, anteropost. 24 mm., transv. 14 mm.
Diameters of dp_4, anteropost. 24 mm., transv. 15 mm.
Length of milk-molar series, dp_2 to dp_4, 71 mm.
Depth of jaw at dp_4, 42 mm.

MERYCHIPPUS ISONESUS (Cope).

A right upper molar (no. 10670, Univ. Cal. Col. Vert. Palae.) agrees in size and general characters with the corresponding tooth in the type of *M. isonesus*, and may be referred provisionally to that species.

Diameters of molar, anteropost. 18 mm., transv. 22 mm.

MERYCHIPPUS, sp. indet. (1).

Figs. 2 and 3.

A second species of *Merychippus* of an almost brachyodont type is represented by two upper premolars, p^1 and p^2, in a fragment of the maxillary bone (no. 10659, Univ. Calif. Col. Vert.

2

3

Figs. 2 and 3.—*Merychippus*, sp. indet. (1), first and second upper premolars, no. 10659, natural size.

Palae.) The p^2 has about the size and proportions of the corresponding tooth in *M. calimarius* except that it is much lower crowned. It differs from the latter also in some other important respects. P^1 is much larger than that of *M. calimarius*, which it exceeds by nearly one-half its anteroposterior diameter. It is

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inserted by two large fangs. The crown of p^2, which is apparently half worn away, is entirely clear of the alveolar border and is really brachyodont in form, although it is elongate and the valleys and fossettes are well filled with cement. The difference in form and development of the protoconule is an important character which distinguishes this tooth from that of *M. calimarius*. This cusp is united with the protocone at the triturating surface by a wide isthmus, but is rounded in outline and shows no tendency to unite with the metaconule. There is also no anterior fold, or crotchet, on the metaconule which leaves the anterior fossette uninterruptedly confluent with the median internal valley. The form and character of the protoloph is like that of the corresponding tooth of a specimen (no. 583, U. S. National Museum coll.) referred by Leidy to *M. insignis*,[1] and of species of *Pliohippus* from the upper Miocene formations.

This specimen from the Virgin Valley may represent a new species of *Merychippus* with *Protohippus* or *Pliohippus* affinities.

Diameters of p^1, anteropost. 15 mm., transv. 8.5 mm.

Diameters of p^2, anteropost. 24 mm., transv. 20? mm.

MERYCHIPPUS, sp. indet. (2).

A last upper molar of the right side (no. 10677, Univ. Calif. Col. Vert. Palae.) represents a small species of *Merychippus* from the Virgin Valley beds. In size this tooth about equals or is slightly larger than the type of *M. seversus* (Cope), but has not more than one-half the height of crown.

Diameters of molar, anteropost. 17.5 mm., transv. 17.5 mm.

Height of crown (outside), 13 mm., (inside) 9 mm.

MERYCHIPPUS, sp. indet. (3).

Two other isolated teeth, both upper molars of the right side (nos. 10669 and 10675, Univ. Calif. Col. Vert. Palae.), indicate a fourth species of *Merychippus* in this collection. They are larger than the last tooth described, and appear to have been, in the unworn stage, comparatively higher and straighter crowned

[1] Jour. Acad. Sci., Phila., vol. 7, (2), 1869, p. 296, pl. 17, fig. 5.
This specimen, also with teeth of a very low-crowned type, is from the Niobrara river, Nebraska, and is probably from the middle or lower Miocene formation which is exposed, underlying the upper Miocene, in the vicinity of Fort Niobrara.

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than any of the above described teeth, yet not so high crowned as in many species of *Merychippus* from the Mascall beds and other middle Miocene formations.

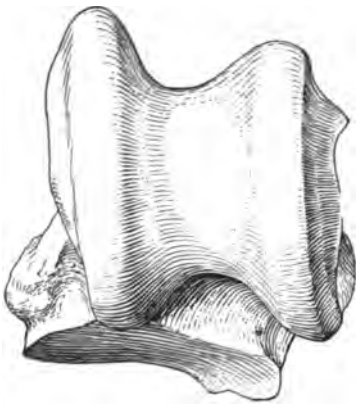
Diameters of molar no. 10669, anteropost. 18 mm., transv. 24 mm.

Diameters of molar no. 10675, anteropost. 18 mm., transv. 22.5 mm.

EQUINE ASTRAGALI.

Figs. 4-7.

Two equine astragali in this collection (nos. 10657 and 10721, Univ. Calif. Col. Vert. Palae.), representing widely different



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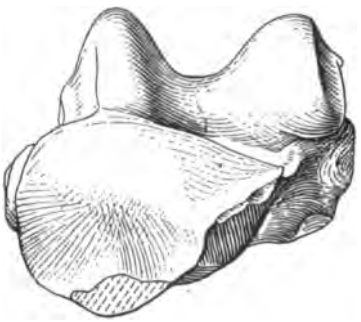

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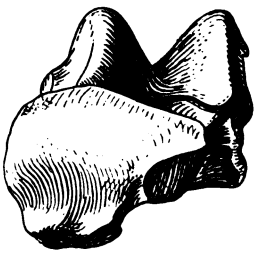

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Figs. 4 and 5.—*Hypohippus?* astragalus, no. 10657, natural size.
Figs. 6 and 7.—*Parahippus?* astragalus, no. 10721, natural size.

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types of horses, are of especial interest since they suggest opposite lines of development, of the hind feet, from an intermediate type such as that of *Mesohippus*. The first astragalus (see figs. 4 and 5) is short and broad with widely open tibial groove, and well rounded keels. The inner keel is not deflected at its distal extremity as in *Mesohippus*, but terminates in direct line with its oblique fore and aft plane. The second (figs. 6 and 7) is more elongate, the keels much compressed laterally, and the tibial groove much narrower and more angulate in cross-section. The inner keel is deflected at its distal extremity as in *Mesohippus*, and even to a greater degree than in that genus. The first of these astragali is characteristic of the comparatively short, broad foot of the *Hypohippus* type, and is probably referable to a species of that genus. The second is of uncertain reference, but indicates a more highly specialized foot of the long and slender type like that of *Neohipparion whitneyi* or some of the more specialized forms of feet belonging to species of the *Parahippus* group. In its more important characters the *Mesohippus* astragalus is intermediate between these two forms.

PALAEOMERYX? BOREALIS (Cope).

Figs. 8 and 9.

The last specimens of importance to be considered in this little collection from the Virgin Valley locality are two isolated teeth which are referable to *Palaeomeryx*, as that genus is at present

8 9

Figs. 8 and 9.—*Palaeomeryx? borealis* (Cope). Last upper molar, no. 10676, natural size.

understood. The more characteristic tooth (no. 10676) is a portion of a last upper molar of the right side, with the inner walls of the protocone and hypocone broken away. The crown is short, brachyodont, with well developed external styles and well marked external ribs. It agrees very nearly in size with the

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corresponding tooth of *P. borealis* (Cope) and resembles it in some other respects. As in *P. borealis,* the adjacent horns of the inner crescents are completely fused at their tips, and there is a well defined spur, or crotchet, extending forward into the anterior fossette. The anteroposterior diameter of the tooth is 19.5 mm., transverse (estimated) 22 mm.

The other tooth referred to this genus is a considerably worn premolar of the left side (no. 10671). It shows nothing of special importance.

CONCLUSIONS.

Without exception the specimens of this little collection indicate species of a middle or lower Miocene age. Compared with the known forms of the Mascall beds of the John Day Valley, the species appear to differ slightly in every case, and the species of *Merychippus* represented are apparently somewhat more primitive throughout. This leads to the conclusion that the Virgin Valley beds are not newer, at least, and suggests that they may be, in fact, somewhat older than the Mascall formation.

Date of Issue, December 2, 1908.

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UNIVERSITY OF CALIFORNIA PUBLICATIONS

BULLETIN OF THE DEPARTMENT OF

GEOLOGY

Vol. 5, No. 16, pp. 243-269 ANDREW C. LAWSON, Editor

STRATIGRAPHY AND PALAEONTOLOGY OF THE SAN PABLO FORMATION IN MIDDLE CALIFORNIA.

BY

CHARLES E. WEAVER.

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INTRODUCTION.

One of the many problems connected with the interpretation of the Tertiary stratigraphy and palaeontology of middle California is the relation of the San Pablo formation to the other Tertiary horizons. Just what division of the Californian Tertiary the San Pablo formation represents has not been universally agreed upon, neither is it certain what constitutes the base and top of the formation. The chief aim of this investigation has

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been to determine the extent, character, and stratigraphic position of these beds in the Coast Ranges of central California. In addition an attempt has been made to study the fauna and show its relation to that of the Monterey and the Merced.

This investigation was begun several years ago by Professor J. C. Merriam. Important collections of fossils were made at several localities and much detailed stratigraphic work was done in the field. Two years ago a continuation of this investigation was suggested to the writer and the present paper is the result of a study of the known San Pablo outcrops of middle California and of their fauna. A number of detailed sections were made across the strike of the beds and collections of fossils were made at intervals along the sections. From the information obtained an attempt has been made to set forth the main characteristics of the formation from base to top, and the variations in the character of the strata at the same horizon in different localities within the area studied. The study of the fauna shows the presence of seventy-three species. The formation as a whole is a distinct feature of the Tertiary of middle California.

HISTORICAL REVIEW.

The formation now known as the San Pablo was first referred to by T. A. Conrad[1] in 1857 in the Pacific Railroad Reports. He described several fossils collected in the San Pablo Bay area and considered them to be of Miocene age and to correspond to the Miocene fauna of Virginia. In 1865 J. D. Whitney in his Report on the Geological Survey of California refers to the San Pablo localities at Kirker's Pass and Corral Hollow, and on the basis of the fossil leaves considered the formation to be Pliocene in age. In the same volume W. M. Gabb referred[2] to the San Pablo beds at Kirker's Pass. He gave a short list of its fauna and described its stratigraphic relations, and on the basis of its large percentage of living species called it Pliocene. He stated that it lies conformably upon the Miocene and is overlain conformably by ashes and tuff. In volume 2, Palaeontology of California

[1] Pacific R. R. Reports, vol. 6, p. 70.

[2] Geol. Surv. of Calif. Geology, vol. I, p. 31.

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State Geological Survey, Gabb[3] mentions the presence of *Scutella (Clypeaster) gabbi* at San Pablo Bay, Walnut Creek, and in the vicinity of Mount Diablo and called the beds in which it occurred, Miocene. At Kirker's Pass he mentions the presence of *Trophon ponderosum,* and calls the beds Pliocene.

In 1891, H. W. Turner[4] in his paper on the Geology of Mount Diablo refers to the localities at Kirker's Pass, Corral Hollow and Railroad Ranch. Collections of fossils were made and the fossil leaves were turned over to Ward and Lesquereux for identification. A part of these were considered as belonging to the Pliocene and a part to the Miocene. The most important evidence for referring the San Pablo to the Pliocene he considers to be the character of the tuff and conglomerates which are made up chiefly of detrital material of hornblende and pyroxene andesites. These eruptions were considered to have taken place in Pliocene time. The andesitic material at Kirker's Pass was considered probably to have been derived from volcanic areas to the north of San Pablo Bay. He concludes that these localities are of Pliocene age notwithstanding the Miocene aspect of a part of the flora.

In 1895, Mr. George H. Ashley in his paper on the Neocene Stratigraphy[5] of the Santa Cruz Mountains in California, mentions fossiliferous transitional beds south of Half Moon Bay which lie conformably upon the Monterey and beneath the Merced. These beds became known later as the Purisima. Whether they are the equivalent of the San Pablo or not, is not certain.

In May, 1898, Professor J. C. Merriam[6] in The Distribution of the Neocene Sea-Urchins of Middle California gives a description of the San Pablo formation in the San Pablo Bay section, and correlates it with the beds at Kirker's Pass. He states that "at all of the localities at which the San Pablo is known, it is characterized faunally by the presence of a peculiar assemblage of genera and species in which *Astrodapsis* is the

[3] Geol. Surv. of Calif. Palaeontology, vol. 2, p. 109.
[4] Bull. Geol. Soc. Amer., vol. 2, p. 383.
[5] Proc. Cal. Acad. Sc., 2d Ser., vol. 5, pp. 273-367.
[6] Bull. Dept. Geol. Univ. Calif., vol. 2, no. 4, pp. 109-118.

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most abundant and easily recognized form. The fauna is known so far by about fifty species, of which nearly one-third are peculiar to these beds, about one-fourth are known also from the Contra Costa County Miocene, and one-sixth from the Merced." Further he says: "The sea-urchins form the most prominent organic feature of the formation, neither of the *Astrodapsis* species being found outside of it." Lithologically he characterizes it "as containing a considerable thickness of tuffs and ashes, most prominent in the upper portion of the formation, and a peculiar weathering of the sandstone." He considers the possibility of a break between the San Pablo and the Contra Costa County Miocene and states that the stratigraphic relations of the San Pablo to the Merced are not definitely known. He finds the fauna of the San Pablo more closely related to the Contra Costa County Miocene than to the Merced fauna. As to the age he considers that it probably represents the middle Neocene.

In September, 1908, Dr. H. W. Fairbanks correlated Neocene beds in the San Luis range with the San Pablo of middle California.

In 1898, Mr. H. W. Turner[7] in his paper on the Rocks of the Coast Ranges of California gives quite a detailed description of the San Pablo localities in the vicinity of Mount Diablo and Corral Hollow. Large collections of fossils were made and on the basis of the ratio of the living and fossil forms he regards the formation as of lower Pliocene age. At Kirker's Pass he divides the formation into four divisions, the lowermost being composed of fine-grained white shales and volcanic detritus. The second division is composed of sandstone containing a majority of the marine fossil shells. Above this are blue beds composed of volcanic conglomerates, tuff, and sandstone. In the topmost portion of this were found leaves and above all were layers of volcanic pumice. The total thickness of the formation at Kirker's Pass he considers to be six hundred meters. At Railroad Ranch and Corral Hollow similar fossil leaves were found. He suggests a possible correlation with a part of the auriferous gravels in the Sierra Nevada.

[7] Journal of Geol., vol. 6, pp. 483-499.

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In 1899, Mr. F. M. Anderson[8] in his paper on the Geology of Point Reyes Peninsula states that there are beds near the town of Tomales which are supposed to be of San Pablo age.

In 1904, Professor J. C. Merriam,[9] in his paper on the Fauna of the Lower Miocene in California, states that the Contra Costa County Miocene contains two faunal zones and that the upper division has its nearest affinities with the San Pablo but is distinguished from it by the presence of *Clypeaster brewerianus, Trochita costellata,* and several other forms.

In the same year in a paper by Mr. H. L. Haehl[10] and Dr. Ralph Arnold on the Miocene Diabase of the Santa Cruz Mountains in San Mateo County, California, the Purisima formation is described. It is described as an extensive series of conglomerates, fine-grained sandstones and shales. They lie unconformably upon the Vaqueros sandstone and Monterey shale. The upper limit was considered to be the base of the Merced. Its age was considered to represent the lower or perhaps the middle Pliocene.

In 1905, Dr. H. W. Fairbanks,[11] in his description of the San Luis Folio, states that "overlying the Monterey shale unconformably is a series of soft white sandstone, conglomerate, diatomaceous beds and flinty shales which represent the San Pablo group. The names Pismo and Santa Margarita were given to these strata. Fossils showed them to be of Neocene age, but whether Miocene or Pliocene was not certain.

In the same year Mr. V. C. Osmont[12] published a paper on a Geological Section of the Coast Ranges north of San Francisco Bay. In this he gives a description of several areas in which San Pablo strata are found. Strata of undoubted San Pablo age occur in the core of the hills on the west side of Carneros Creek. It is considered as San Pablo by reason of its physical appearance and its fossil fauna. Prevolcanic beds made up of four hundred feet of a very coarse hard sandstone and yellow to buff colored sandy shales are found between Freestone and the mouth

[8] Bull. Dept. Geol. Univ. Calif., vol. 2, no. 5.
[9] Bull. Dept. Geol. Univ. Calif., vol. 3, no. 16, pp. 377-381.
[10] Proc. Am. Phil. Soc., vol. 43, pp. 15-53.
[11] San Luis Folio: Geologic Atlas U. S., folio 101, U. S. Geological Survey, Washington.
[12] Bull. Dept. Geol. Univ. Calif., vol. 4, no. 3, pp. 39-87.

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of Tomales Bay. Marine fossils were found in the beds and he considers them to be of San Pablo age. Similar beds were observed at Pleasant's and Capay Valleys, and these are also considered as San Pablo.

In 1905 Mr. F. M. Anderson,[13] in a stratigraphic study of the Mount Diablo Range of California, divides the later Neocene beds into the Coalinga and the Etchegoin beds. The former he considers to be the equivalent of the uppermost Contra Costa County Miocene and the Etchegoin beds as the equivalent of the San Pablo beds. He considers the San Pablo beds at San Pablo Bay and Kirker's Pass to represent only the lower portion of the Etchegoin beds or rather the Etchegoin sands. They rest unconformably upon the Coalinga beds. He considers them as probably of Pliocene age.

In 1906 Dr. Ralph Arnold,[14] in his paper on the Tertiary and Quaternary Pectens of California, gives an extended account of the San Pablo areas in various parts of the state. He states: "the formation at the type locality consists of a series of sandstones, tuffs and ashes with an approximate total thickness of between fifteen hundred and two thousand feet. At this locality it rests apparently conformably upon the Contra Costa County Miocene. In the Salinas Valley and at many other places formations which are probably the equivalent of the San Pablo rest unconformably upon the Monterey shale. In the Santa Cruz quadrangle beds containing the supposedly characteristic San Pablo echinoderm *Astrodapsis tumidus* Rémond, rest unconformably upon the Monterey and are overlain conformably by at least a part of the Purisima (Lower Pliocene)." Lists of fossils are given from the San Pablo at the type localities and from the Santa Margarita formation in the Salinas Valley, which he considers as probably the equivalent of the San Pablo. He describes the Purisima formation as consisting of a series of conglomerates, fine-grained sandstones, and sandy shales having a total thickness of about eight hundred feet and being typically developed in the vicinity of the lower portion of Purisima Creek, San Mateo County. He shows that from field and laboratory

[13] Proc. Calif. Acad. Sci. Geology, vol. 2, no. 2, p. 174.
[14] U. S. Geological Survey. Professional paper 47, p. 22.

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studies of the materials in the two formations it is evident that they are quite intimately related. Taken as a whole, he considers the Purisima fauna as younger than the aggregate San Pablo fauna. He concludes that the greater part of the San Pablo should without question be placed in the Miocene while the major portion of the Purisima is undoubtedly Pliocene.

GEOGRAPHIC DISTRIBUTION.[15]

The San Pablo formation is widely distributed in the Coast Ranges of California. To the north of San Francisco Bay it occurs as a long narrow belt lying on the eastern flank of the Blue Ridge and extending in a northwesterly-southeasterly direction from the town of Vacaville to Lake County. The belt averages about four miles in width and perhaps thirty in length. A second occurrence lies in the hills between the towns of Napa and Sonoma. Here it outcrops in the eastern bluff of Carneros Ridge and along the valley of Carneros Creek. It occupies a belt about one mile in width and six miles in length.

The type locality where it has been most thoroughly studied occurs in Contra Costa County in the vicinity of San Pablo Bay. Here it occupies a V-shaped belt extending in a synclinal fold from El Cierbo on the north in a southeasterly direction to near the head of Franklin Cañon, where it turns and swings around to the southwest and emerges on San Pablo Bay about one mile south of the town of Rodeo. This is one of the best known occurrences of the San Pablo in middle California.

Farther east this formation is again well represented in the district north and south of Mount Diablo. It occurs as a broad belt extending in a northwest to southeast direction on the northern flank of Mount Diablo. This belt lies near the foothills of the mountain and outcrops prominently in the hills on either side of Kirker's Pass and Markeley Cañon and extends from there to Karquinez Strait. On the south side of the mountain

[15] In the compilation of the statement of geographic distribution and stratigraphic relationships of the San Pablo, the manuscript geological maps of the Concord, San Francisco, Mt. Diablo, and Napa quadrangles prepared for the U. S. Geological Survey from the field studies of Andrew C. Lawson, John C. Merriam, G. D. Louderback and C. E. Weaver have been freely used, and many of the facts here stated in print for the first time are clearly set forth in these maps.

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there is a similar and nearly parallel belt extending from the alluvium-covered foothills of the San Joaquin on the southeast across the range to San Ramon Valley on the northwest. As a rule the outcrops of this formation stand out very prominently especially in Tassajero Cañon and Green Valley and farther to the west along Shell Ridge. Here it is covered by the alluvium of San Ramon Valley. West of Mount Diablo it outcrops from the town of Walnut Creek southward in a belt extending nearly parallel to San Ramon Valley, occurring in the isolated hills in the valley, in the hills on either side of the valley, and in the bed of the creek itself. Farther west it again occurs along both sides of the ridge extending southeasterly from the town of Lafayette. South of here it occurs as a belt extending around the ridge between San Ramon Valley and Bolinger Cañon.

To the south the San Pablo outcrops east of the town of Livermore and north of the town of Tesla. It occurs as a belt extending nearly east and west but with a slight northwesterly trend. It covers an area of at least ten miles long by half a mile wide.

These isolated areas are all exposed to view, due to the folding of the strata, and probably represent what was once during San Pablo time a nearly continuous area of deposition.

STRATIGRAPHIC RELATIONS.

The formations comprising the middle Tertiary of Central California are the Monterey and San Pablo. In most cases the stratigraphic relations existing between them are not very clearly defined. The two formations when considered as a whole are entirely different. The Monterey formation is composed of a number of alternating divisions of sandstone and shale, both the lower and upper being sandstone. The uppermost sandstone division of the Monterey is very difficult to distinguish on a lithological basis from some facies of the San Pablo beds. In the majority of instances the San Pablo appears to rest conformably upon the Monterey sandstone and hence it becomes very difficult to determine at just what point to draw the line of separation.

San Pablo Section.—The section which has been most thoroughly studied, and the one from which the formation takes its

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name, occurs in Contra Costa County on the east side of San Pablo Bay near the town of Rodeo. It extends as a belt about one mile in width from El Cierbo southeasterly to the head of Franklin Cañon and from there it swings around to the southwest and reaches San Pablo Bay just north of the powder works at Hercules. Here the San Pablo, together with the Chico, Monterey, and Pinole Tuff, has been folded into a synclinal trough. Just south of here the Monterey is very completely developed and is composed of nine well defined divisions of sandstone and shale. The uppermost division is known as the Quercan sandstone and it very closely resembles the characteristic San Pablo sandstone. In this region the Monterey apparently lies unconformably beneath the San Pablo. Areal mapping shows the different divisions of the Monterey to extend diagonally beneath the strike of the San Pablo beds. On the north flank of this syncline all of the formations dip at very high angles toward the axis. Here the Monterey is represented by the two upper divisions only, the Herculean shale member and the Quercan sandstone. They rest unconformably upon the Chico, and although no actual exposures reveal them unconformably beneath the San Pablo, yet from observations taken on the south flank it would seem most probable that an unconformity exists here also.

The section made across the strike of these beds is well defined and was measured in detail by following the cliffs along the bay shore. On the south side of the syncline the dip is much lower than on the north and only the Monterey, San Pablo, and Pinole Tuff are exposed in the fold. Near the base of the San Pablo the average dip is about 30 degrees north, and this gradually decreases towards the top until at the contact with the tuff it is only 20 degrees. The general character and appearance of the strata is the same on both flanks of the syncline. The total thickness of the strata in this section is about seventeen hundred feet. The formation is made up of conglomerates, thick-bedded sandstones which are in places conglomeratic and cross-bedded, sandy shales and clay shales. The sandstones generally have a bright blue or gray-blue color, but very often weather to a yellowish or reddish tinge. The conglomerates appear to be most abundant in the lower half of the formation.

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North of Mt. Diablo.—On the north side of Mount Diablo the San Pablo occurs as a long narrow belt having a width of about three-fourths of a mile and a length of about fifteen miles which extends in a general northwest and southeast direction. It is underlain by the Monterey formation and overlain by the Pinole Tuff and Orindan formation. All of these formations dip north. Two sections were measured in detail across the strike of the San Pablo formation. One of these is located along the east side of Kirker's Creek and the other along Markeley Cañon. In general the character of the strata at the same relative positions in the two sections is the same. However, the thick beds of white shale which outcrop so prominently at the base of the section in Kirker's Creek, are not well represented at the base in Markeley Cañon. Here the San Pablo and Monterey at the line of contact are apparently conformable. In the Kirker's Creek section some thick-bedded coarse gray sandstones which very closely resemble the characteristic San Pablo sandstones occur between the Monterey shales and the lower white shale member of the San Pablo. In the western portion of Contra Costa County the Monterey formation is separated into nine well defined divisions of sandstones and shale, but to the east in the vicinity of Mount Diablo these divisions lose their identity. However, it has seemed best to consider the sandstone at the base of the white San Pablo shale to be the equivalent of the upper sandstone member of the Monterey farther west and to make the base of the San Pablo the line separating the sandstone from the white ash beds. Thus we have, as the lower portion of the San Pablo, strata composed of white chalky shale followed by coarse thick-bedded sandstones and conglomerates. Overlying these are several feet of shale containing fossil leaves. These are followed by conglomerates and an extensive series of coarse-grained, conglomeratic, gray sandstones in which are numerous fine bands of conglomerate. These sandstones are very often cross-bedded. Besides these there are beds of shale, shaly sandstones, and fossils. Above these are great thicknesses of bluish-gray sandstones. These sandstones are overlain by tuffs intermixed with conglomerates. At San Pablo Bay, Carneros Creek, and Pleasant's Valley, tuffs rest upon the San Pablo and they

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have all been correlated with the Pinole Tuff. Provisionally the tuff here is also considered as the equivalent of the Pinole Tuff. The average thickness of the San Pablo along this belt is about one thousand feet.

South of Mt. Diablo.—On the south side of Mount Diablo there is a belt of San Pablo strata comparable in extent and volume with that on the north side. It extends along the Black Hills in a general northwest to southeast direction. When traced to the northwest it extends up through Shell Ridge and passes underneath the alluvium of San Ramon Valley. In the vicinity of Shell Ridge it lies upon the Monterey, but to the southeastward the Monterey thins out and disappears and the San Pablo rests upon the Tejon. The Orindan beds lie above it. The Tejon, San Pablo, and Orindan have all been overturned and in places the Tejon has been partly thrust over upon the San Pablo. The average dip is about 80 degrees north, but near the contact with the Tejon it decreases to 50 degrees with the Tejon uppermost. These sections were measured across the strike of the San Pablo belt at Tassajero Cañon, Railroad Ranch, and Green Valley. The average thickness is about twelve hundred feet. The characteristic features of this belt are about the same as those on the north side except that the white chalky shale at the base on the north side is represented by a thick-bedded, buff-colored, shaly sandstone. This is followed by conglomeratic fossiliferous sandstone with a small amount of shale. Near the middle of the formation there is a belt of conglomerate consisting of pebbles made of quartz, chert, and volcanic rock, firmly cemented together in a bluish-gray matrix. This belt has a thickness of over one hundred and twenty feet, and is followed by about one hundred feet of coarse-grained, gray, fossiliferous sandstone containing lenses of a fine-grained conglomerate and showing a distinct cross bedding. When followed westward this band of conglomerate becomes less distinct. It passes into numerous alternations of coarse sandstone and conglomerate and finally into a conglomeratic sandstone. In the exposures along the road from Railroad Ranch it appears only as conglomeratic sandstone. Above this there are sandstones interbedded with shales and near the top there is a series of thin-bedded sand-

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stones, leaf-bearing shales, and conglomerates. These are well exposed in the open cuts opposite the Railroad Ranch reservoir. Above this are coarse, yellowish-gray, conglomeratic sandstones. Whether they are a part of the San Pablo or belong to the Orindan is not certain. In other words, the contact here between the San Pablo and Orindan is uncertain. There is no tuff between them as there is in the section at Kirker's Creek. The outcrops are in most cases well defined and are destitute of any great amount of soil covering.

San Ramon Valley Region.—In the hills on either side of San Ramon Valley there are outcrops of San Pablo strata. About six miles southwest of the town of Walnut Creek they appear on the two flanks of a syncline in the ridge extending southeasterly from the town of Lafayette. The Monterey, San Pablo and Orindan formations and the Pinole Tuff have all participated in the folding. A section was made across the strike of the San Pablo in this area. The line of contact between the Monterey and San Pablo could not be definitely determined upon a lithological basis. The Monterey formation in this section has almost exactly the same lithological appearance as the San Pablo. The lower portion of the Monterey sandstone contains a large number of hard cherty shale concretions which are not at all characteristic of the San Pablo. The line of contact has been drawn upon a palaeontological basis entirely and on either side of this line the sandstones of both the San Pablo and Monterey are exactly alike, and no change can be seen in passing from one to the other, except that the San Pablo strata outcrop in rough ragged edges while the Monterey weathers to a soil and gives the hills a smooth rounded outline with few bold outcrops.

The upper contact with the tuff and Orindan formation is sharp and well defined. The thickness of the San Pablo in this section is about six hundred feet and it is composed almost entirely of a coarse-grained, thick-bedded, yellowish-gray sandstone which in places is conglomeratic. A few small layers of sandy shale are present but not prominent. No tuffs nor chalky shales were seen. The dip is steep on either side toward the axis of the syncline, but varies somewhat along the line of the strike.

Farther south near the town of Danville and on the western

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side of the valley the San Pablo again outcrops on the two sides of an anticlinal axis. The axis of the anticline extends along the ridge between Bolinger Cañon and San Ramon Valley. The core is composed of Monterey and the axis pitches in a southeasterly direction, so that the San Pablo of the eastern flank swings around and covers the Monterey on the south side of the ridge and then passes southwesterly and outcrops in the hills on both sides of Bolinger Cañon forming the western flank of the anticline. Here again the Monterey and San Pablo can not be separated on a lithological basis but only by means of fossils. The thickness of the San Pablo measured across the strike just below the town of Danville is about seven hundred feet. Near the base it is made up of heavy, thick-bedded, coarse, gray, and sometimes conglomeratic sandstones with occasional small bands of shale or conglomerate. Farther up in the series conglomerates become more abundant and near the uppermost part of the strata which are exposed there is an abundance of shale. The uppermost beds are covered unconformably by the alluvium of the valley. No white chalky shales were seen at the base nor tuffs at the top. On the eastern limb of the anticline the strata dip at an average angle of about 50 degrees to the southeast.

In San Ramon Valley, extending southwest from the town of Walnut Creek, San Pablo strata are again well exposed. Well marked outcrops occur in the creek bed at Walnut Creek and in the low hills along the east side of the creek and Southern Pacific railway track. About two miles south of the town of Walnut Creek a detailed section was measured across the strike of these beds. The section extends through the highest point on Sugar Loaf Mountain, then across the valley and into the hills on the west side of the railroad track. The strata dip at an angle of about 55 degrees east. These beds lie upon the Monterey, but the line of contact is not certain as there are no well defined outcrops. The strata have the same general appearance but at points to the south the contact has been determined upon a palaeontological basis. No white chalky shales were seen. The most prominent outcrop near the base is in the Southern Pacific railway cut on the west side of the county road just before it crosses the town of Walnut Creek. Coarse, thick-bedded, gray

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sandstones are predominant. Several bands of shale are present and also several prominent belts of conglomerate but none of these exceed two feet in thickness. Fossils are abundant. On the east side of the valley along the line of this same section the strata are well exposed. For the most part they are composed of heavy, thick-bedded, gray sandstones which are very conglomeratic in places, and beds of conglomerate and shale. Near the top one belt of shale has a thickness of over fifty feet. The topmost strata are composed of a yellowish-gray, thick-bedded sandstone. Beyond this only the Orindan is exposed, with no tuff intervening.

Corral Hollow.—In the vicinity of Corral Hollow the San Pablo has a thickness of about twelve hundred feet and outcrops for a distance of nearly ten miles. The strata dip to the north at low angles. The strike is nearly east and west. The Monterey appears to be absent and the San Pablo lies upon the Tejon. Above, it is overlain by the Orindan. The line of contact cannot be determined with certainty as one seems to grade into the other. The strata are composed mostly of heavy, thick-bedded bluish-gray sandstones, shales, and conglomerates. The shale bands predominate at the base. In these occur fossil leaves.

North of Karquinez Straits.—On the north side of Karquinez Straits the San Pablo is represented in Carneros Creek Cañon between the towns of Napa and Sonoma. Farther north it occurs in the hills on either side of Pleasant's Valley extending from Vacaville to Winters.

In the hills between Napa and Sonoma the San Pablo is represented by a volume of sandstone, shale and conglomerate having a total thickness of over fifteen hundred feet. It rests apparently unconformably upon the Tejon sandstone and dips northwesterly at an angle of 60 degrees into the hills. It lies unconformably beneath the Pliocene volcanics. No Monterey occurs in this region. The base is composed of thin-bedded shaly sandstones, shale and sandstones. Higher up the formation is composed of thick-bedded, soft, bluish-gray sandstones, resembling in places almost a volcanic ash. One or two narrow seams of shale are present.

In the Pleasant's Valley section the San Pablo lies directly

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but unconformably upon the Shasta-Chico series. The Shasta-Chico strata make up the greater part of the Blue Ridge and dip at an angle of about 45 degrees to the northeast. The San Pablo lies upon this and dips in the same general direction, but at an average angle of 20 degrees. Near the base the San Pablo is made up of thick-bedded, buff-colored sandstones. Higher up in the series on the east side of Pleasant's Valley a few shaly bands are present, but the sandstone has a distinct gray color and is often thin-bedded. They are overlain unconformably by the Pinole Tuff, in other places by andesite and in still other places by the Orindan formation. Neither the Eocene nor Monterey is present. The total thickness is over two thousand feet. The white chalky shale member which occurs at the base in the Mt. Diablo region is not present at Carneros Creek nor Pleasant's Valley.

Original Extent of Deposits.—The geographical conditions existing in middle California during San Pablo time appear to have been somewhat peculiar. That there was an interval of time between the close of the Monterey and the beginning of the San Pablo appears evident from the fact of the unconformity existing between them in the San Pablo Bay region. Farther east sedimentation appears to have been continuous and in places there were local deposits of volcanic ash. From the cross-bedded and conglomeratic character of the sandstones and the thick seams of conglomerate, it appears that the greater part of the San Pablo strata indicate shallow water conditions. No outcrops occur south of Pinole or west of Lafayette and it would seem that in that region during San Pablo time there was a land surface. There appears to have been some volcanic activity during the time of deposition. This became especially evident to the north after the close of the San Pablo. It is probable that the chief volcanic activity during San Pablo time was to the east, perhaps even as far as the Sierra Nevada. The andesite pebbles which make up the conglomerates in Tassajero Cañon are similar to andesites from that region and none are known as flows in the San Pablo of the Coast Ranges of middle California.

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CORRELATION.

The San Pablo formation is characterized faunally by the presence of seventy-three species and fifty-three genera, a large number of which are peculiar to the San Pablo alone while others range back into the Miocene or Monterey and many more have survived to the present time and may be found in the living fauna along the Pacific Coast of North America. A study of the fauna collected at various horizons in the sections made at several localities shows certain forms to be characteristic of the lower beds and others of the upper. Whether this is sufficient evidence for dividing the San Pablo into an upper and a lower division is not certain, but it remains a fact that several distinctive and characteristic species are confined to certain horizons within the formation. At no one locality within the area studied is it probable that the San Pablo formation in its entirety is represented.

Upon a palaeontological basis the strata at San Pablo Bay may be divided into two divisions. Professor Merriam has already clearly shown the occurrence and range of the echinoids in the section. *Scutella gabbi* appears to be confined to the lower part of the formation, while the upper part is characterized by the presence of *Astrodapsis tumidus*. Certain of the species seem to be closely associated with the Astrodapsis beds and are not present in the Scutella zone. Among those in this section are *Pecten pabloensis, Pectunculus* near *patulus, Mulinea densata,* and *Olivella boetica.* Altogether seventeen species have been collected from this section.

In the Kirker's Pass locality the thickness of the strata as measured in cross-section amounts to over one thousand feet. Turner's estimate of six hundred meters is due to the fact that he included in the San Pablo formation the uppermost division of tuffs and ashes, which are here placed in the Pinole Tuff. Forty-nine species were collected from the Kirker's Pass section. Nearly all of these came from the layer B of Turner, which overlies the white chalky shales and underlies the volcanic conglomerates and sandstones. The lower division, or rather the *Scutella gabbi* zone, which occurs in the San Pablo Bay district,

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does not appear to be represented in the section at Kirker's Pass, or Markeley Cañon. It is possible that the white chalky shales at the base may be the equivalent of the Scutella zone, but there is no direct evidence of any kind to support it. The total fauna is much more varied in the number of species than at San Pablo bay, but it approaches more closely in its affinities that of the *Astrodapsis tumidus* zone, or the upper division.

On the south side of Mt. Diablo, in the localities at Tassajero Cañon and Railroad Ranch, the San Pablo fauna, while not very large, appears to bear its closest resemblance to that of the Astrodapsis zone, and to be the equivalent of the San Pablo at Kirker's Pass and at Markeley Cañon. The lower beds here contain large numbers of the species *Ostrea titan*. Whether this is a characteristic lower San Pablo fossil or not, is uncertain. It occurs in the lower beds in the San Pablo Bay section; it occurs only in the lowermost beds at Tassajero Cañon, and it is probable that the two are nearly equivalent. The fossil leaves referred to by Mr. H. W. Turner[16] came from the conglomerate tuff and sandstone overlying the fossiliferous sandstone, and according to Lesquereux are considered as being of Pliocene age. They were determined as follows:

Diospyros virginiana, var. *turneri* Lx.
Magnolia californica Lx.
Laurus, cf. *canariensis* Heer.
Virburnum, cf. *rugosus* Pers.
Vitis, sp. (?)

Those collected later, in 1897, by Professor Merriam and Mr. Turner are also considered Pliocene, but the general appearance of the bed would seem to indicate that they do not belong to the San Pablo, but rather to the Pinole Tuff. The list is as follows:

Fern, probably *Pteris*, but very fragmentary.
Populus, female catkin.
Alnus, fruits and leaves.
Castanea, sp., leaf.
Vaccinum, sp., single small leaf.
Arbutus, sp., numerous well preserved leaves and fragments.

In the upper beds at Tassajero Cañon are strata composed of vast numbers of specimens of *Pseudocardium gabbi*. This form

[16] Jour. Geol., vol. 6, pp. 483-499.

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appears to be characteristic of the upper San Pablo. To the south, just below Danville, fossiliferous beds occur, which yielded a typical upper San Pablo fauna. They occur in a quarry just west of the county road, where some of the outcropping strata are very largely composed of fossil marine shells. Altogether eighteen species are present, and they are mostly characteristic of the Astrodapsis zone. Among the more characteristic of these are *Astrodapsis tumidus, Chione succincta, Pecten veatchii, Pectunculus* near *patulus,* and *Pseudocardium gabbi.*

At Walnut Creek the San Pablo is represented by both the upper and lower beds. The lower or *Scutella gabbi* beds outcrop in Walnut Creek, just out of the town. Fossils are abundant, but rarely well preserved. To the westward at Lafayette San Pablo fossils occur, and while they are few in number of species, yet they indicate the lower portion, or perhaps the Scutella zone.

On the north side of San Francisco bay the San Pablo occurs at Carneros Creek, and to the northwest of Vacaville in Pleasant's Valley. The fossils collected at Pleasant's Valley were very poorly preserved and fragmentary. *Pseudocardium gabbi* was recognized. Provisionally this belt has been considered San Pablo, but more on petrographical and stratigraphical evidence than upon palaeontological. It lies unconformably upon the Shasta-Chico series, and is overlaid by the Orindan, the Pinole Tuff, and lavas. The beds at Carneros Creek are certainly San Pablo in age. While the fauna is not large, it is typically San Pablo. The general physical appearance of the rock is also characteristic of the San Pablo at the localities where it is best developed. Just what portion of the formation it represents is not clear, as the fauna is not large and not characteristic of any one zone. The species occurring here are given in the general correlation table and are not listed separately.

In the following table is given a complete list of all the known San Pablo species from the localities studied in middle California, and their characteristic situation whether in the lower middle or upper portions is also given. Such forms as range back into the Monterey and those occurring in the Merced, Wildcat, Santa Margarita, Etchegoin, Purisima, and those living in the waters of the Pacific Coast of North America at the present time are also indicated.

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	Living	Lower San Pablo	Middle San Pablo	Upper San Pablo	San Pablo Bay	Walnut Creek	Lafayette	Kirker's Pass	Danville	Carneros Creek	Rail Road Ranch	Upper Monterey	Santa Margarita	Purisima	Merced
ASTEROIDEA															
Asterias remondi Gabb					x										
ECHINOIDEA															
Astrodapsis tumidus Rémond			x	x	x	x		x	x				x		
Astrodapsis whitneyi Rémond				x			x								
Scutella gabbi (Rémond)		x	x		x	x									
PELECYPODA															
Arca microdonta Conrad			x										x		
Cardium blandum Gould	x	x		x		x		x							
Cardium corbis Martyn	x	x	x	x		x		x	x						
Clementia subdiphana Carpenter	x	x								x					
Cyrena californica Gabb								x							
Chione fluctifraga Sowerby	x							x							x
Chione succincta Valenciennes	x			x					x			x			x
Clidiophora punctata Conrad	x	x			x		x					x		x	

	Living	Lower San Pablo	Middle San Pablo	Upper San Pablo	San Pablo Bay	Walnut Creek	Lafayette	Kirker's Pass	Danville	Carneros Creek	Rail Road Ranch	Upper Monterey	Santa Margarita	Purisima	Merced
Dosinia ponderosa Gray	×							×						×	
Gari alata Gabb								×							
Glycimeris generosa Gould	×			×		×			×		×	×			
Mulinea densata Conrad		×	×	×	×	×		×				×			
Modiola recta Conrad	×	×		×			×	×				×		×	×
Modiola capax Conrad	×		×	×				×			×				
Macoma nasuta Conrad	×		×	×		×		×				×		×	
Macoma secta Conrad	×			×		×	×								
Machaera patula Dixon	×	×					×					×			
Nucula divaricata Conrad	×									×					
Ostrea titan Conrad		×				×		×				×			
Ostrea bourgeoisi Rémond								×							
Pachydesma? crassatelloides Conrad	×			×				×							
Pecten (Lyropecten) crassicardo Conrad								×					×		
Pecten vealchii Gabb				×					×						

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	Listing	Lower San Pablo	Middle San Pablo	Upper San Pablo	San Pablo Bay	Walnut Creek	Lafayette	Kirker's Pass	Danville	Carneros Creek	Rail Road Ranch	Upper Monterey	Santa Margarita	Purisima	Merced
Pecten pabloensis Conrad		×	×	×	×	×	×	×	×		×				
Pectunculus patulus Conrad			×	×	×	×		×	×		×	×			
Pinna, n. sp.			×	×				×	×						
Pseudocardium gabbi Rémond				×			×	×			×		×		
Saxidomus squalibus Deshayes	×							×							
Saxidomus gracilis Gould	×	×	×			×		×	×			×			
Standella falcata Gould	×	×	×					×							
Standella californica Conrad	×		×				×								
Solen rosaceus Carpenter	×	×	×			×	×	×				×			
Serripes, sp.								×							
Schizothoerus?, sp.			×						×						
Tapes staminea Conrad	×	×						×							×
Tapes staleyi Gabb								×						×	×
Yoldia cooperi Gabb	×		×									×		×	
Zirphaea, sp.			×					×	×			×			

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GASTEROPODA	Livine	Lower San Pablo	Middle San Pablo	Upper San Pablo	San Pablo Bay	Walnut Creek	Lafayette	Kirker's Pass	Danville	Carneros Creek	Rail Road Ranch	Upper Monterey	Santa Margarita	Purisima	Merced
Bittium asperum Gabb	×							×					×		×
Crepidula praerupta Conrad															×
Crepidula adunca Sowerby	×							×							
Crepidula grandis Middendorf	×									×					
Crepidula, n. sp.				×											
Chrysodomus tabulatus Baird	×			×					×				×		
Calliostoma, n. sp.		×				×		×							
Calliostoma splendens Carpenter	×	×													
Cerithidea?, sp.				×			×								
Fusus, sp.								×							
Lunatia lewisii Gould	×	×			×	×		×						×	×
Litorina planaxis Nuttall	×							×							
Litorina remondi Gabb		×						×							
Monoceras engonatum Conrad	×	×	×		×	×									×
Natica callosa Gabb, n. var.												×			

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	Living	Lower San Pablo	Middle San Pablo	Upper San Pablo	San Pablo Bay	Walnut Creek	Lafayette	Kirker's Pass	Danville	Carneros Creek	Ball Road Ranch	Upper Monterey	Santa Margarita	Purisima	Merced
Nevevita recluziana Petit	×	×	×	×	×	×	×	×				×		×	
Nassa perpinguis Hinds	×		×		×			×	×			×			
Nassa mendica Gould	×	×		×				×	×					×	
Neptunea recurva Gabb	×									×					
Olivella boetica Carpenter	×	×	×		×	×		×				×			
Ocinebra lurida Carpenter	×	×				×		×							
Purpura saxicola Valenciennes	×					×		×							
Purpura canaliculata Duclos	×	×	×		×		×	×							×
Purpura crispata Chemnitz	×	×	×		×			×					×		×
Priene oregonensis Carpenter	×	×	×		×								×		
Ranella californica Hinds	×							×							
Scalaria, sp.						×		×		×					
Trochita fiosa Gabb		×	×		×		×	×	×			×	×		×
Trochita, n. sp.		×		×		×		×	×		×				
Trochita inornata Gabb			×	×		×		×	×			×			
Trophon ponderosum Gabb								×				×			

The San Pablo beds in middle California appear to be represented by beds of equivalent age in other parts of the Coast Ranges. To the south of San Francisco Bay several formations have been described which resemble very closely both in their physical characteristics and in the fauna contained in them, the San Pablo beds in the bay region. In the Mount Diablo Range, Anderson has named and described the Etchegoin beds which extend over a large area and possess an immense thickness. They too lie unconformably upon all the underlying formations. Immediately below the Etchegoin beds are the Coalinga beds which he considers to be older than the San Pablo and younger than the Monterey. If so, the Coalinga beds represent a period of sedimentation between the close of Monterey time and the beginning of the San Pablo. No such beds appear in middle California, but a time interval is indicated by the unconformity between the Monterey and San Pablo in the San Pablo Bay region. The lower portion of the Etchegoin beds or rather the Etchegoin sands he considers as the equivalent of the San Pablo beds at San Pablo Bay. This portion is composed of unconsolidated sands or gravels in which a characteristic blue or gray color predominates. The sands have in general a coarse pebbly texture often forming beds of conglomerate and in many cases having the appearance of volcanic ash. The following are some of the more important characteristic San Pablo fossils which occur in the Etchegoin formation:

Pseudocardium gabbi.
Neverita recluziana.
Nassa californica.
Astrodapsis tumidus.
Macoma nasuta.
Trophon ponderosum.
Tapes staleyi.
Macoma secta.

A comparison of the Etchegoin fauna shows many of the species to be similar to those of the San Pablo and it thus seems best to correlate them as being equivalent in age.

In the Salinas Valley there is a formation known as the Santa Margarita composed of sandstones, shales, and conglomerate. Sandstones appear to predominate. This entire series was considered by Dr. Fairbanks to represent the San Pablo. An abundant fauna has been listed from here, and among the more characteristic forms which occur also in the San Pablo are

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Astrodapsis tumidus, Ostrea titan, Pecten crassicardo, Pseudocardium gabbi, and *Trochita filosa.* The fauna seems to be sufficiently characteristic to warrant its being correlated with the San Pablo beds but whether all of it should represent the San Pablo or only a part, is not certain.

In San Mateo County in the vicinity of Purisima Creek beds known as the Purisima formation are composed largely of conglomerates, fine sandstones, and sandy shales and have a thickness of about eight hundred feet. A very large number of fossils have been collected. Many of these are common in the San Pablo, among which are *Macoma nasuta, Modiola recta, Tapes staleyi, Yoldia cooperi, Chrysodomus tabulatus, Nassa californica,* and *Neverita recluziana.* Arnold considers the Purisima as Pliocene and possibly a little younger than the San Pablo. A large number of species present in the Purisima occur in the Merced. Arnold estimates that about 30 per cent. of the fauna is extinct. At the present time it is impossible to say whether the two formations are equivalent or not.

The relations of the San Pablo to the Monterey Miocene are clearly brought out in the San Pablo Bay section from detailed areal mapping. The Monterey lies unconformably beneath the San Pablo and gives evidence of a period of deformation and erosion between the close of Monterey deposition and the beginning of the San Pablo. In the other sections in middle California no such relations between the San Pablo and Monterey can be made out. It is only upon a palaeontological basis that they can be distinguished. In the Salinas Valley and other localities in the southern part of the state the unconformable relations are exceptionally well marked. The upper Monterey Miocene faunal zone is very closely allied to the San Pablo, and where the two lie in contact it becomes very difficult to draw the line of separation. There are several characteristic fossils from the upper Monterey zone, among which are *Trochita costellata, Scutella breweriana* and *Mulinea densata.* The latter is also very abundant in the San Pablo. Out of the total San Pablo fauna twenty-one species occur in the Monterey, or 28.7 per cent.

The next formation situated geologically above the San Pablo in middle California is the Merced. At no locality are the two

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known to lie in contact, but when the faunas of the two are compared that of the Merced is found to be younger. That is, there are less forms common to the Monterey and a larger per cent. are living to-day on the coast than is the case with the San Pablo. Out of the total number of species in the latter twenty are common to the Merced.

So far in correlating the San Pablo it has been referred to the Pacific Coast localities. Here many species are identical but when a comparison is made with the Tertiary faunas of the Atlantic states and Europe, correlation has necessarily to be based upon the maxima of genera. The areas selected for correlation were the Maryland and Virginia districts and Florida; and in Europe the district of Touraine, in France; the Vienna Basin and the Pliocene of England and Italy.

In correlating with the faunas of the Maryland and the Virginia Miocene, no distinction was made between the upper and the lower divisions. The entire Miocene fauna was considered. Nineteen genera were found in common but no species. No marine Pliocene forms were available for comparison, so correlation is made with the Caloosahatchie formation or the Pliocene of Florida. Twenty-nine genera were found to be common to the San Pablo and no species. Very little satisfaction is gained from the correlation with the European Pliocene. In the Vienna Basin only five genera were found common, in the Miocene from the district of Touraine, France, only three genera are common, and in the Pliocene of Italy only two. In the Pliocene of England twelve are common. The evidence obtained here is inconclusive.

The following table shows the relation of the San Pablo to the Miocene and Pliocene, and to the recent fauna on the Pacific Coast of North America:

Number of San Pablo species	73
In Monterey	21 = 28.7%
In the Merced	20 = 27.4%
Living	41 = 56%

According to the classification of Lyell used in dividing the Tertiary on the percentage of living species it would be impossible to assign the San Pablo to the Miocene. The large number

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of living forms makes it Pliocene. The fact that a time interval is represented between the Monterey and San Pablo gives also additional weight to the argument. Considering the sum total of evidence it seems best to regard the San Pablo formation as being of lower Pliocene age.

SUMMARY.

The San Pablo formation as represented in middle California is composed of coarse, thick-bedded sandstones, shales, and conglomerates, with a large admixture of volcanic tuff and ash. It varies in its physical characteristics at different localities and ranges in thickness up to over three thousand feet. Its characteristic color is a bluish-gray which upon weathering changes to a buff color. At San Pablo Bay it lies unconformably upon the Monterey, but at the other localities in this part of the state no break between them can be seen. The total number of marine species contained in the formation is seventy-three, and many of these are characteristic forms. Twenty-one, or 28.7 per cent. of them range down into the Monterey and 56 per cent. are still living in the waters of the Pacific Coast today. From the large per cent. of living species it has seemed best to consider the San Pablo formation as Pliocene, and as representing the lower portion of that system.

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BULLETIN OF THE DEPARTMENT OF

GEOLOGY

Vol. 5, No. 17, pp. 271-274, Pls. 21-22 ANDREW C. LAWSON, Editor

NEW ECHINOIDS FROM THE TERTIARY OF CALIFORNIA.

BY

CHARLES E. WEAVER.

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INTRODUCTION.

The new echinoid forms here described and figured have been examined in the course of a series of studies of the Tertiary of California carried on by the author for several years. The greater part of the included material was obtained and the preliminary studies made by Professor Merriam. For the excellent material represented by these new species the author is much indebted to the late Dr. Stephen Bowers, to Professor James Perrin Smith, and to Mr. Walter Stalder.

CLYPEASTER BOWERSI, n. sp.

Pl. 21, fig. 1; and pl. 22, fig. 1.

The test of this form is very large and thick. The largest specimens measured 119 mm. in diameter. The outline seen from above is circular to elliptical. The margins are swollen and the summit very slightly elevated. On the posterior margin is a

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faint re-entrant angle opposite the anal opening. The petals are broad and nearly closed at the extremity. The median interporiferous zones are broad, while the outer rows of pores converge at the ends so as almost to enclose them. The tuberculation is uniform on both the upper and lower surfaces and the tubercules are of nearly the same size over the whole test.

The actinal surface is strongly concave and the actinostome deeply sunken. The ambulacral furrows are very deep and extend from the actinostome to the margin.

Clypeaster bowersi differs considerably from the other members of this genus on the Pacific coast. It is not far removed from *C. breunigei* Laube, which occurs in the Eocene in the Lybian Desert of Africa. *C. bowersi* is nearly twice as large as *C. breunigei* and is ellipsoidal in outline with thick margins, while the latter is pentagonal and has thin margins. The upper surface of the former is only slightly arched, while the apical system of the latter is conical and then gradually slopes to the margin. They differ also in the character of the petals and in the position of the anal pore. In *C. bowersi* the petals are broad and the poriferous zones lie nearly parallel. The anus is situated on the actinal surface at a distance from the margin about equal to its diameter.

Clypeaster bowersi shows a close relationship to *Echinanthus rosaceus* Gray. It differs in that it is much flatter, the superior surface of *E. rosaceus* being more strongly convex. The actinostome of the former is sunken in a cavity which narrows gradually and is of much greater extent than in *E. rosaceus*. In *E. rosaceus* the ambulacral areas are more or less swollen and rise above the general level of the test, while in *C. bowersi* they are nearly at the same level as the interambulacral areas. The posterior ambulacral petals are the longest and the odd ambulacral petal is the shortest in *E. rosaceus*. In *C. bowersi* the odd ambulacral petal is the longest and the remaining four are of equal size.

Dimensions: Maximum width 100 mm.; maximum length 119 mm.; maximum thickness 37 mm.

Occurrence: Colorado Desert. Associated with a fauna presumed to be of Miocene age.

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SCUTELLA PERRINI, n. sp.

Pl. 22, fig. 2.

The outline of the test from above is circular to elliptical. The upper surface is very slightly arched and the margin of the test is moderately thin. The apical system is excentric and small. The ambulacral petals are rather broad, sometimes very slightly elevated, open at the ends, and extending to within a short distance of the margin. The poriferous zone is about two-thirds as broad as the enclosed ambulacral space. The anal pore is marginal.

The lower surface of the test is slightly concave. Faint undivided ambulacral grooves pass from the mouth to the margin. The tubercles are of the same size on the upper and lower surfaces.

Scutella perrini differs from *Scutella breweriana* in that the petals are of uneven length and the apical system excentric, while in *S. breweriana* the apical system is central. The test of *S. perrini* also reaches greater size than is known in *S. breweriana.*

Dimensions: Maximum width 40 mm.; maximum length 45 mm.; maximum thickness 6 mm.

Occurrence: In beds presumably of Miocene age near Coalinga, California. Other specimens closely resembling this form have been found at San Gregorio, California, in the Purisima formation.

LINTHIA(?) CALIFORNICA, n. sp.

Pl. 21, fig. 2.

The outline of the test from above is elliptical. The anterior groove is deep. The apical system is small and situated slightly anterior to the center. The central portion of the lateral interambulacral plates forms a series of irregular ridges extending from the apical system to the margin. The posterior interambulacral area is elevated. The three anterior ambulacra are nearly equal in size and larger than the posterior areas as far as known. The poriferous zones of the ambulacra are narrow, but the pores are large. The specimen is a poorly preserved cast

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and further data are lacking. This species has been referred to *Linthia* rather than to *Schizaster* on account of the more central position of the apical system.

Dimensions: Maximum width 14 mm.; maximum length 19 mm.; maximum thickness 7 mm.

Occurrence: In Contra Costa County, California, about one mile west of Bear Valley in the lowest member of the Monterey series.

SCHIZASTER(?) STALDERI, n. sp.

Pl. 21, fig. 3.

Test distinctly cordate in form, with all of the petals deeply sunken. The depression of the anterior petal deeply notches the anterior margin. The petals of the bivium are very short. The mouth-opening is situated very far forward. The anal opening is not shown. As all of the known specimens are casts, the nature of the plates of the test is only imperfectly shown.

Dimensions: Maximum length 30.5 mm.; maximum width 28 mm.

Occurrence: This species is represented by a small series of specimens obtained by Mr. Walter Stalder in Humboldt County, California, in beds presumed to represent the Wild Cat series of Lawson.

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EXPLANATION OF PLATE 22.

All figures natural size.

Fig. 1. *Clypeaster bowersi*, n. sp. Inferior side.

Fig. 2. *Scutella perrini*, n. sp.

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BULLETIN OF THE DEPARTMENT OF

GEOLOGY

Vol. 5, No. 18, pp. 275-283, Pls. 23-24 ANDREW C. LAWSON, Editor

NOTES ON ECHINOIDS FROM THE TERTIARY OF CALIFORNIA

BY

R. W. PACK.

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INTRODUCTION.

The following notes were prepared in the course of an examination of an extensive series of the Tertiary echinoids of California carried on by the writer during the past year. Much of the material was obtained by Professor John C. Merriam, and the study of it was commenced by him. For some excellent material the writer is indebted to Professor James Perrin Smith, to Dr. Ralph Arnold, and to Mr. Frank M. Anderson. It has been thought advisable to include descriptions of one or two of the known species for which the existing descriptions are meager, as well as to describe and figure the new forms.

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SPATANGUS (?) PACHECOENSIS, n. sp.

Pl. 23, figs. 4 and 5.

Test usually small, average diameter 25 mm. Fragments have been found with a diameter of 48 mm. Outline sub-circular, truncated and notched anteriorly. Test thick, upper surface strongly arched from the margin. Lower surface flat, forming a distinct angle with the upper surface at the margin. Apical system small, eccentric anteriorly. Lateral and posterior petals of almost equal length, reaching about three-fourths of the distance to the margin; slender, and closed at the ends; poriferous zones very slightly sunken, forming two-thirds of the width of the petal. Anterior petal in a broad and fairly deep groove, and apparently reaching the margin; pores few and set wide apart in contrast to the lateral and posterior petals, where the pores are numerous and conjugate. Interambulacral plates broadly V-shaped; very slightly raised in the center to form two low interambulacral ridges. Ambulacral plates not widening rapidly beyond the ends of the petals.

Dimensions: Longitudinal diameter 23 mm.

Occurrence: This species has been found at but one locality northwest of Pacheco, Contra Costa County, in the Tejon. All specimens yet found are poorly preserved, being casts or impressions, and are badly crushed.

In the lowest portion of the beds containing this species, numerous specimens of *Schizaster lecontei* were found. The range of this latter species is, therefore, not limited to the Martinez as was at first thought, but runs well up into the Tejon.

SCUTELLA FAIRBANKSI Arnold.

Pl. 23, fig. 1.

Scutella fairbanksi (Merriam, M. S.), Arnold, U. S. G. S. Bull. 309, pl. 29, fig. 9.

Test sub-circular in outline, much depressed; edges markedly thin. Upper surface regularly arched from the margin, apex central. Apical system small, and central; petals extend one-half to two-thirds the distance to the margin. Lateral and posterior petals symmetrical, slender, almost closed at the ends, both inner and outer rows of pores converging gradually for the last

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half of their length. Poriferous zones broad, together forming over half the width of the petal. Anterior petal broad, wide open at the end, inner rows of pores diverging gradually to the end of the petal; poriferous zones about the same width as in the other petals, but enclosed area much broader. Ambulacral plates enlarging and area widening rapidly from the ends of the lateral and posterior petals, less rapidly from the anterior one. Two or three pairs of pores in rapidly diverging rows are traceable from the ends of the petals. Actinal surface flat, mouth opening central and slightly sunken. Ambulacral furrows deep, traceable to the margin. Near the margin these furrows show a slight tendency to branch, but in the specimens examined they were too poorly preserved to trace.

Anal pore supramarginal, separated from the edge by a distance equal to its own diameter. Tubercles somewhat larger on the actinal surface, especially near the mouth.

Dimensions: Longitudinal diameter 65 mm.; height 8 mm.

Occurrence: In the Vaqueros formation in Torry and Sespe cañons, Ventura County.

This species is closely allied to *Scutella gabbi,* from which it differs in attaining a greater size, in having a slightly undulating, marginal outline, in having deeper and better marked furrows on the actinal surface, and in having the anal pore entirely on the upper surface. From *Scutella interlineata* it differs in having a central apical system.

SCUTELLA (?) NORRISI, n. sp.

Pl. 23, fig. 3.

Test sub-circular in general outline, with deep, broad, marginal notches in the edges of the ambulacral areas. The two posterior notches are much deeper than are the anterior ones, and truncate the posterior interambulacral space on either side of the median line, shaping the posterior end of the test into a prominent process. The test when viewed from above has a leaf-like appearance. Test much depressed, edges markedly thin, abactinal surface very slightly arched, apex central; actinal surface flat or gently concave. Mouth central, slightly sunken; ambulacral furrows poorly shown in the specimens examined, but evi-

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dently branch but little, if at all. Main ambulacral grooves continue from the mouth to the margin, entering the marginal notches. Anal pore small, inframarginal. Ambulacral star central. Petals extend about three-fourths the distance to the margin and not entirely closed at the ends.

Dimensions: Longitudinal diameter 55 mm.

Occurrence: This species has been found in the Vaqueros formation, five miles northwest of the Stone Cañon coal mine, Monterey County; and at San Juan River, near La Panza, San Luis Obispo County.

SCUTASTER, new genus.

Test circular, depressed, ambulacral star small. Lunules in the prolongation of the petals of the trivium; and either lacking in the bivium and posterior interambulacral space, or not placed in the same relative positions as on the anterior portion of the test.

SCUTASTER ANDERSONI, n. gen. and sp.

Pl. 23, fig. 2.

Test sub-circular in outline, edges markedly thin. Upper surface regularly arched from the margin; apex anterior to the center. Apical system small and apparently central. Ambulacral star small; petals extending slightly less than half way to the margin of the test, closed at the ends. Lateral petals broader than the posterior ones, but of almost the same length. Poriferous zones broad, and continuing full width almost to the ends of the petals. In the posterior petals the interporiferous area forms about one-third the width of the petal. Poriferous zones of the lateral petals equal in width to those of the posterior petals, but enclosed area broader. In the extension of the three anterior petals are broad lunules, over half as long as the petals; shallow grooves extend from the lunules to the margin. Anterior lunule slightly farther from the apical system than are the lateral ones. From the ends of the posterior petals the plates enlarge, and the area broadens rapidly. No lunules were seen here, nor in the posterior interambulacral space. They may be represented by marginal notches, as the posterior edge of the specimen is lacking.

Dimensions: Transverse diameter 44 mm.; height 8 mm.

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Occurrence: The single known specimen of this species was found in Miocene east of Muir, Contra Costa County. This specimen was obtained by Mr. D. C. Birtch of the University of California on one of the field excursions in March, 1909, and was placed by him in the University collections in palaeontology.

ASTRODAPSIS FERNANDOENSIS, n. sp.

Pl. 24, figs. 3 and 4.

Test small; sub-oval in outline, anterior end rounded, posterior end slightly pointed; much depressed, upper surface very slightly convex, apex central; edges rounded. Apical system central; petals extend to margin, wide open at the end, raised near the apical system but almost flush with the surface of the test near the margin. Poriferous zones very narrow, together forming about one-fourth the width of the petal. The two posterior petals are gently convex toward the median line through the posterior interambulacral space. A broad, shallow depression occupies the center of the interambulacral areas; the two secondary depressions so prominent in *Astrodapsis antiselli* are almost entirely lacking. Actinal surface gently concave, furrows poorly marked, but apparently branched as in *Astrodapsis antiselli*. Anal pore sub-marginal, large, and oval in outline. The posterior end of the test is produced beyond the pore to a small point, particularly noticeable in the smaller specimens. Tubercles very large, and set in well defined pits; apparently the same on upper and lower surfaces.

Dimensions: Longitudinal diameter 51 mm.; transverse diameter 39 mm.; maximum height 8 mm.

Occurrence: Fernando formation (Lower Pliocene?), Elsemere Cañon, Los Angeles County.

ASTRODAPSIS ANTISELLI, Conrad; n. var. ARNOLDI.

Pl. 24, figs. 1 and 2.

1856. *Astrodapsis antiselli* Conrad Proc. Acad. Nat. Sci. Phila., vol. 8, pp. 312-316.

1856. *Astrodapsis antiselli* Conrad Pac. R. R. Repts., vol. 7, p. 196, pl. 10, figs. 1 and 2.

1908. *Astrodapsis antiselli* Conrad (Arnold) Proc. U. S. Nat. Mus., vol. 34, pl. 25, fig. 10.

1909. *Astrodapsis antiselli* Conrad (Arnold) Folio 162, U. S. G. S., fig. 59.

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Test oval to sub-circular in outline, longitudinal axis slightly longer than transverse one; depressed, abactinal surface gently arched, actinal surface slightly concave. Mouth opening central, anal pore small, submarginal to inframarginal. Ambulacral furrows distinct, sending out two branches a little over half way from the mouth to the margin. The main ambulacral furrows continue on the upper surface, passing through the middle of the petals to the apical system. The branching furrows continue across the margins to the upper surface, running over the middle portion of small ridges which extend half way from the margin to the apical system, along the line of junction of the ambulacral and interambulacral plates.

Apical system central, slightly sunken. Ambulacral star symmetrical, petals raised, wide open at the ends, and continuing to the margin. Inner rows of pores almost parallel for last three-fourths of their length, diverging slightly near the margin. Outer rows diverging for about half the distance to the margin; from here to the margin they contract gradually toward the inner rows. Near the margin the pores are almost in the middle of the ambulacral plates. Interporiferous area forming almost two-thirds of the width of the petal. Middle of the interambulacral area occupied by a wide depression extending from margin to apical system. Lesser depressions in the ambulacral areas between the two small ridges and the petals, extending half way to the apical system.

Tubercles on abactinal surface large on ridges and in interporiferous area, irregular in size and spacing: on actinal surface large and regularly spaced.

Dimensions: Longitudinal diameter 62 mm.

Occurrence: Salinas Valley, Monterey County.

This variety differs from typical *Astrodapsis antiselli* in having a markedly thin edge, in having the petals raised somewhat higher, and in having the arch of the abactinal surface commence some distance in from the edge, and not at the margin of the test.

Astrodapsis antiselli shows quite a wide variation, most noticeable in the thickness of the edge of the test, and the degree to which the petals are raised. With more material available it will probably be found desirable to form several varieties. A very

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close relationship exists between *Astrodapsis antiselli* and *Astrodapsis tumidus,* and it is probable that the latter should be considered only as a variety of the former species. *Astrodapsis whitneyi* has evidently been confused with one of the variations of *Astrodapsis tumidus.* The original description apparently refers to a form which appears in the uppermost San Pablo in Contra Costa County, and also in the upper Miocene (the Santa Margarita formation of Arnold) near Coalinga. This form shows some resemblance to the new form *Scutella* (*?*) *norrisi* from Stone Cañon, especially noticeable in the prominent posterior ambulacral notches.

ECHINARACHINUS EXCENTRICUS Eschscholtz.

1826. *Scutella excentricus* Eschscholtz, Zool. Atlas, pl. 20, fig. 2.
1846. *Echinarachinus excentricus* Esch. Valenciennes, Voyage Venus, pl. 10.
1856. *Scutella striatula* Conrad, Pac. R. R. Repts., vol. 7, pl. 9, figs. 1*a*, *b*, and 2.
1873. *Echinarachinus excentricus* Esch. Agassiz, Mus. Comp. Zool. Harv. Univ., Mem. 3, pp. 107, 524; pl. 13*a*, figs. 1-4.
1888. *Echinarachinus excentricus* Esch. (Cooper) Cal. State Min. Bur.; 7th Ann. Rep. State Mineralogist, p. 271.
1898. *Echinarachinus excentricus* Esch. (Merriam) Univ. Calif. Publ. Geol., vol. 2, p. 110.
1899. *Echinarachinus excentricus* Esch. (Merriam) Proc. Cal. Acad. Sci., 3rd ser., Geol., vol. 1, p. 170; pl. 22, fig. 8.
1903. *Echinarachinus excentricus* Esch. (Arnold) Cal. Acad. Sci. Mem., vol. 3, p. 91.
1907. *Echinarachinus excentricus* Esch. (Arnold) U. S. G. S. Bull. 322, pl. 24, fig. 8.

Test sub-pentagonal to sub-circular in outline, slightly broader than long; edges thin, frequently notched posteriorly. Vertex slightly back of center of test, but well in front of eccentric apical system. Ratio of distance from apical system to posterior margin compared with distance from apical system to anterior margin varies from 1 : 1.4 to 1 : 2.4. Upper surface of test slopes up gently from margin to ends of petals, from here it forms a regular arch. Actinal surface flat with very slight tendency to form a sunken mouth. Petals broad, open at the ends, very unequal in size. Anterior petal straight, twice the length of the posterior ones, with broad interporiferous space enclosed by nar-

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row poriferous bands, which narrow down sharply near the end of the petal. In other petals poriferous bands are full width almost to ends of petals. Lateral petals straight, diverging at an angle of from 105° to 130°; interporiferous space narrower, poriferous bands wider than in anterior petal. Posterior petals oval, poriferous bands broad.

Mouth opening eccentric, corresponding to vertex of test, slightly sunken. Anal pore inframarginal. Ambulacral furrows well marked in posterior part of actinal surface, branching close to mouth, main branches continuing almost parallel for last three-fourths of their length. A second branch enters the interambulacral areas about half way from mouth to margin; many smaller branches from all main ones. Three or four of the stronger interambulacral furrows continue on upper surface of test to the upper ends of the petals. In posterior and sometimes in lateral petals a central furrow reaches almost to the apical system. Furrows poorly marked in anterior part of actinal surface.

Tubercles larger on actinal than on abactinal surface, especially noticeable near mouth, standing here in well defined pits.

Occurrence: Living—Alaska to San Pedro (Cooper). Pleistocene—San Pedro (Cooper, Arnold), San Diego, Santa Barbara (Arnold), (?) Seven Mile Beach. Pliocene—San Fernando, (?) San Diego (Cooper); Santa Clara Valley (Arnold).

Though closely resembling *Echinarachinus gibbsii, Echinarachinus excentricus* is probably not descended from it, for the more recent and not the older specimens of *Echinarachinus excentricus* show the closer relationship to the older species. Specimens from the Pleistocene of San Diego show a very low degree of eccentricity, have very thin edges, and quite long but slightly curved posterior petals. The same is true of all the specimens examined which were referred to the Pliocene.

ECHINARACHINUS GIBBSII Rémond.

1863. *Scutella gibbsii* Rémond Cal. Acad. Sci., vol. 3, p. 13.

1868. *Scutella gibbsii* Rémond Gabb, Pal. of Calif., vol. 3, pl. 13, figs. 66 and 66*a*.

1899. *Echinarachinus gibbsii* Rémond (Merriam) Proc. Calif. Acad. Sci., 3rd ser., Geol., vol. 1, p. 169; pl. 22, fig. 7.

1907. *Echinarachinus ashleyi* (Merriam, M. S.), Arnold, U. S. G. S. Bull. 322, pl. 24, figs. 6 and 7.

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This form differs from *Echinarachinus excentricus* in the following particulars: The outline of the test varies from quadrate-oval to sub-pentagonal, being seldom sub-circular. The transverse diameter is rarely longer than the longitudinal one. The eccentricity is usually greater, the ratio which the distance of the apical shield from the posterior margin bears to the distance from the shield to the anterior margin varies from 1 : 1.9 to 1 : 2.9. The arch of the upper surface commences at the margin and not at the ends of the petals; also the margin is somewhat thicker. The lateral petals diverge with a smaller angle, from 80° to 105°. The apex is more eccentric posteriorly. The lateral petals are almost twice the length of the posterior ones, which latter are often almost circular in outline.

Occurrence: Lower Pliocene or upper Miocene; Capitola, San Gregorio, Coalinga, Kettleman Hills, Buena Vista Lake.

The separation of a form *Echinarachinus ashleyi,* based upon the sub-pentagonal outline of the test, seems hardly justified. This variety was suggested by Professor Merriam after the examination of a small amount of material from Capitola. Since then a large number of specimens of *Echinarachinus gibbsii* were collected by him at a single locality in the Kettleman Hills, from a bed but four feet in thickness. In this collection specimens were found with almost any outline from quadrate-oval to sub-pentagonal, the transverse diameter sometimes being the greater one.

Issued July 21, 1909.

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EXPLANATION OF PLATE 23.

All figures natural size.

Fig. 1. *Scutella fairbanksi* Arnold. Vaqueros formation, lower Miocene; Ventura County (?).

Fig. 2. *Scutaster andersoni*, n. gen. and sp. Upper surface of only known specimen. Miocene, one mile northeast of Muir, Contra Costa County.

Fig. 3. *Scutella* (?) *norrisi*, n. sp. Inferior surface of weathered specimen showing outline of test. Vaqueros formation, lower Miocene; five miles northwest of Stone Cañon coal mine, Monterey County.

Fig. 4. *Spatangus* (?) *pachecoensis*, n. sp. Upper surface of fragment of large specimen, showing form of interambulacral plates. Tejon formation, Eocene, one and one-half miles northwest of Pacheco, Contra Costa County.

Fig. 5. *Spatangus* (?) *pachecoensis*, n. sp. Cast of test. Same locality as fig. 4.

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EXPLANATION OF PLATE 24.

All figures natural size.

Fig. 1. *Astrodapsis antiselli* Conrad, n. var. *arnoldi*. Superior view of test. Santa Margarita formation (?), upper Miocene; Monterey County.

Fig. 2. *Astrodapsis antiselli* Conrad, n. var. *arnoldi*. Inferior surface showing ambulacral furrows. Same specimen as that shown in fig. 1.

Fig. 3. *Astrodapsis fernandoensis*, n. sp. Upper surface showing the outline of the petals. Fernando formation, lower Pliocene (?); Elsemere Cañon, Los Angeles County.

Fig. 4. *Astrodapsis fernandoensis*, n. sp. Inferior surface. Fernando formation, lower Pliocene (?), one mile south of Elsemere Cañon, Los Angeles County.

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UNIVERSITY OF CALIFORNIA PUBLICATIONS

BULLETIN OF THE DEPARTMENT OF

GEOLOGY

Vol. 5, No. 19, pp. 285-289, Pl. 25 ANDREW C. LAWSON, Editor

PAVO CALIFORNICUS, A FOSSIL PEACOCK FROM THE QUATERNARY ASPHALT BEDS OF RANCHO LA BREA.

BY

LOYE HOLMES MILLER.

The Phasianinae constitute a group hitherto unrecorded from the geological horizons represented on this continent, and, as far as I am able to determine, unknown to the Western Hemisphere. The genus *Pavo* seems not to have been noted thus far as a fossil form; hence the occurrence in the Quaternary of California of the remains described in this paper, which seem unquestionably to represent this genus, suggests an interesting problem in the history of geographical distribution. For a discussion of the locality and the formation in which the specimen was found, reference should be made to a paper now being published by Professor John C. Merriam of the University of California,[1] through whose courtesy the present paper is made possible.

Pavo californicus, n. sp. The type specimen (no. 11300, Univ. Calif. Col. Vert. Palae.) is a right tarso-metatarsus obtained in the Quaternary asphalt beds at Rancho La Brea, near Los Angeles, California. The specimen was found at the University of California collecting locality, no. 1059, three feet below the surface, where it was covered by layers containing the characteristic extinct Quaternary mammalian forms of these

[1] See, also, Merriam, J. C., Science, N. S., vol. 24, p. 248, 1906.

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GEOLOGY
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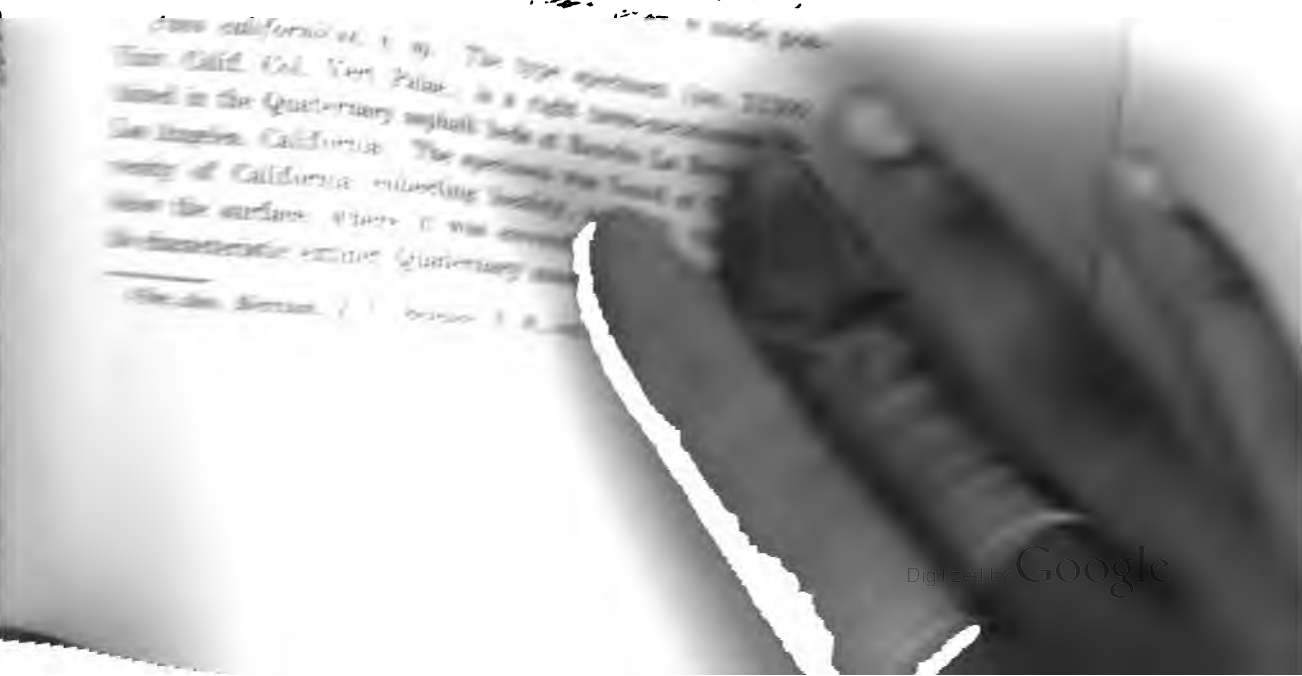
[illegible] californicus, [illegible]. The type specimen (No. [illegible] Univ. Calif. Col. Vert. Palae.) is a right [illegible] in the Quaternary asphalt beds of Rancho La Brea [illegible] Los Angeles, California. The specimen was found [illegible] of California collecting locality [illegible] the surface where it was [illegible] characteristic extinct Quaternary [illegible]



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beds. Other specimens have been found at several localities, and at varying depths in the asphalt of Rancho La Brea.

Besides the characters held in common with the existing peafowls, the species shows the following peculiarities. Tarsus much shorter than in *P. muticus,* actually stouter and hence much more robust. Spur little shorter, much more slender, and placed much higher up on the shank. Lateral toes raised higher above the level of the middle toe. Tarsus longer than in *P. cristatus.* Spur placed higher up. (See pl. 25.)

Milne-Edwards, in his superb plates on the osteology of birds,[2] figures the tarsus of *P. muticus,* from which the form under discussion shows very positive differences. The following table shows the dimensions of *P. muticus,* together with those of the type and two other specimens of *P. californicus* from the same formation:—no. 11299, Univ. Calif. Col. Vert. Palae. and no. 165/1 of the author's collection, both imperfect; also the obtainable dimensions from a live specimen of *P. cristatus.*

Tarso-metatarsus	*P. muticus*	*P. californicus* Type	*P. californicus* No. 165/1	*P. californicus* No. 11299	*P. cristatus*
Length over all (1)	167 mm.	147	....	....	131
Distal end to spur base (2)	48	52	56	53	46
Ratio of (2) to (1)	28%	35%	....	....	30%
Transverse diameter of head	22 mm.	23	....	....	....
Transverse diameter through foot	22	22	....	....	....
Outer trochlea above middle one	5	6	6	6	....
Inner trochlea above middle one	8.5	9	8.5	....	....
Least sagittal diameter above the spur	10.5	12	13	....	....
Least transverse diameter above the spur	8	8	9.5	....	....

Scrutiny of this table will show some of the grosser differences between the type of *P. californicus* and *P. muticus.* The ratio of the total length to that of *P. muticus* is as .82:1, while the ratio of smallest diameters above the spur is 1.14:1 for the sagittal plane and 1:1 for the opposite diameter. We can thus gain some idea of the robustness of the type. The spur occupies a position relatively high up on the shank. The distance from the extremity of the middle trochlea to the base of the spur core

[2] Milne-Edwards, A., "Oiseaux fossiles de la France," Paris, 1867-77.

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is thirty-five per cent. of the total length in the type of *P. californicus* as against twenty-eight per cent. in *P. muticus* and thirty per cent. in *P. cristatus*. The two fragments (165/1 and no. 11299) show absolute dimensions which correspond very closely to those of the type specimen in this regard, and suggest a similar ratio if the total length were obtainable.

The angle formed by the intersection of the long diameter of the shank and the axis of the spur is a constant quantity in four specimens of *P. californicus* at hand. This angle on the proximal side of the spur is less than a right angle and decidedly more acute than in *P. muticus*.

The spur core in *P. californicus* is markedly less robust than in *P. muticus*. The actual length in the type is only slightly less than in that species, yet it is only about three-fourths as broad. In the fragmentary specimens the tip of the spur is wanting, but the angle included between the upper and lower margins indicates similarity to the type. In fact, the four specimens bearing the spur show a surprising degree of uniformity throughout in the development and position of this somewhat superficial structure.

The distal end of the shank shows a distinctive character in the place relation of the three trochleae. The degree of elevation of the lateral toes above the plane of the middle toe is relatively greater in *P. californicus* than in *P. muticus*. The elevation in proportion to the total length of the shank is forty per cent. against twenty-nine per cent. for the outer toe, and fifty-four per cent. against forty-three per cent. for the inner. The distal fragment (no. 11299) shows absolute measurements uniform with the type.

The plantar ridge extending from the hypotarsal prominence to the base of the spur core is a character readily distinguishing *Pavo* from *Gallus* and *Phasianus*. In the type of *P. californicus* this ridge is perforated at its proximal end by a large opening through which the adductor tendon to the outer toe doubtless passed. In Milne-Edwards' figure of *P. muticus*, this opening has a length of 20 mm. The character of this ridge suggests the probability of its being exceedingly variable, and that the extent of ossification is dependent on age. The three specimens

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at hand show this variability, and if the extent of ossification be indicative of age, the type specimen must represent an individual of complete maturity. This opening in the type of *P. californicus* measures only 8 mm. At a distance of 8 mm. from the lower margin of the opening there appears a minute perforation of the ridge, which probably marks the point to which the opening extended in the earlier adult life of the individual. In the two fragments showing the distal end of the shank, the dimensions of this opening are 18 mm. and 10 mm. Proximal fragment no. 11297, though sufficiently long, shows no trace of the spur core, and may reasonably be considered as from a female individual. The dimensions obtained show size equal to that of the type. Unfortunately, the free edge of the plantar ridge is broken away, but sufficient remains to indicate a development quite equal to that of the male, and an opening 18 mm. in length.

We may conclude that the sexual differences in the tarsus of *P. californicus* are limited to the presence or absence of the spur core. It is also probable that the type is from an adult male and represents the species by a very constant group of characters.

Unfortunately, the only available material of *P. cristatus* was a live bird. Very careful measurements of the metatarsal segment in an adult male showed the dimensions in the table above. These are sufficiently different from those of *P. californicus* to demonstrate the distinctness of the two species.

Students of ornithology have in general laid minor stress on palaeontological evidence in the determination of centers of distribution. This fact is due in large measure to the scarcity of fossil material representing existing groups. The encountering of the California peacock so far out of the previously known range of the genus *Pavo* becomes, then, a matter of interest in this connection. The present range of the subfamily in which the peacock is placed is exceedingly limited compared with its former distribution. Phasianine forms are now limited to the Indian Region; but fossil forms are recorded from the Miocene, Pliocene, and Quaternary of Europe, and from the Siwalik beds of India. The occurrence in Europe seems to be in decreasing numbers. Our record is exceedingly imperfect, but with the

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addition of an American form it seems sufficient to indicate that the present range is the focus of a contraction of the distribution area. Whether or not the original center of distribution is within the limits of the existing range is not at present to be determined.

It is impossible, also, to say what influences have so reduced the range of the group when its close relatives, the quails, are of such general distribution. The habits of the two existing Pavos in their native haunts are those of jungle-dwelling fowl. The unusual development and coloring of the plumage render the good hiding places of a timbered country an effective factor in preserving the species. We know nothing of the superficial characters of the fossil species except by inference from the tendency of existing Phasianines to unusual development of the feathers, both as to form and color. The question naturally arises whether *P. californicus,* and such relatives as may have existed with him in the Los Angeles region, suffered extinction because of inability to cope with the more or less treeless condition that prevailed, or came to prevail, in that region. Certainly cursorial power unimpeded by purely ornamental structures would be needed to meet present conditions in that locality. The Road Runner *(Geococcyx californicus),* a ground dweller of such tail development as to earn the popular name of "California Peacock", shows development of the rictrices only, and unquestionably these are of use in guiding the swift movements of the bird in its efforts to escape its enemies, or in pursuit of its active prey. Fleetness of foot and absence of ornate coloring also characterize the coyote, the chief mammalian enemy that such a bird would have had in this open country. Possibly we may look upon physiographic conditions as the prime factors that have cost our fauna this interesting group of birds.

Issued August 14, 1909.

NOTE.—Since the above description went to press, several additional perfect specimens of the tarso-metatarsus of *P. californicus* have been obtained at the type locality. These specimens agree exactly in specific characters with the type specimen.

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EXPLANATION OF PLATE 25.

Pavo californicus, n. sp.

All figures approximately natural size.

Fig. 1.—Tarso-metatarsus, anterior face.

Fig. 2.—Tarso-metatarsus, inner face.

Fig. 3.—Tarso-metatarsus, distal trochleae.

Fig. 4.—Tarso-metatarsus, proximal articular surface.

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BULLETIN OF THE DEPARTMENT OF

GEOLOGY

Vol. 5, No. 20, pp. 291-304, Pl. 26 ANDREW C. LAWSON, Editor

THE SKULL AND DENTITION

OF

AN EXTINCT CAT

CLOSELY ALLIED TO

FELIS ATROX LEIDY

BY

JOHN C. MERRIAM.

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INTRODUCTION.

In December, 1908, Dr. William Bebb of Los Angeles obtained from the asphalt beds at Rancho La Brea, near Los Angeles, a feline skull of extraordinary size, and specifically unlike the cranial parts of any form thus far described from this continent. Dr. Bebb very generously permitted me to make a study of this remarkable specimen, for which my sincere thanks are due him. The skull has recently been presented by Dr. Bebb to the palaeontological museum of the University of California, and has been placed on exhibition.

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The species represented by the skull obtained by Dr. Bebb seems to correspond in characters to the great cat described as *Felis atrox* by Leidy many years ago, from Quaternary beds in the state of Mississippi. This form was evidently one of the largest known species in the group of true cats, and seems to have ranged over at least the southern half of North America.

In comparing the Rancho La Brea specimen with Leidy's description and figure of the type of *Felis atrox,* the writer was very graciously assisted by Mr. Witmer Stone of the Academy of Natural Sciences of Philadelphia, who kindly made an examination of the type with reference to several doubtful points.

HISTORY OF TYPE SPECIMEN OF FELIS ATROX.

In 1853 Joseph Leidy described[1] and figured under the name of *Felis atrox* a portion of a lower jaw of a very large cat which seems to have been obtained in beds of Quaternary age, near Natchez, Mississippi. Regarding the occurrence of this specimen Leidy makes the following statement:

"The specimen belongs to this society (Amer. Philos. Soc.), and when first discovered was in company with several fragments of bones and a few teeth of other extinct mammalia, without labels, but from the condition of their preservation corresponding closely to that of some specimens, in several instances of the same animals, contained in the collection of the Academy of Natural Sciences, from ravines in the neighborhood of Natchez, Mississippi, I have no doubt they were derived from the same locality, and probably constitute the donation entered upon the minutes of the Society, April 1st, 1836, of some fossil remains from the vicinity of Natchez, presented by William Henry Huntington, Esq."

The specimens accompanying the large cat jaw in the collection of Mr. Huntington included remains of *Mastodon, Bison,* and *Equus americanus.* Other remains found at Natchez included *Mastodon, Megalonyx, Mylodon, Bison, Cervus, Equus,* and *Ursus.*

The type specimen consisted of the anterior half of the left

[1] Leidy, Joseph, Amer. Philos. Soc. Trans., New Ser., vol. 10, p. 319.

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ramus of a lower jaw including all of the teeth excepting the incisors. This specimen was designated as the American lion by Leidy, and was shown to represent a species larger than the Recent lion and tiger, and larger than the extinct cave lion of Europe.

Since the description of the type specimen of *Felis atrox*, no other material has been published upon which has been referred to this species. The only described specimen known to the writer which might possibly be referred to this form is the fragmentary type of *Felis imperialis*, which Leidy obtained from deposits presumed to be of Quaternary age occurring in Livermore Valley, California.

OCCURRENCE AND AGE OF RANCHO LA BREA SPECIMEN.

The skull which forms the subject of this paper was obtained by Dr. William Bebb in the asphalt beds at Rancho La Brea, about nine miles west of Los Angeles. It was associated in these deposits with numerous other mammalian remains including the following forms: *Canis indianensis; Canis*, n. sp.; *Smilodon* (?) *californicus; Bison antiquus; Elephas*, sp.; *Mastodon*, sp.; *Camelops*, sp.; *Paramylodon nebrascensis*. The fauna as a whole cannot be considered as other than Quaternary, although the particular division of that system represented is not as yet clearly determined.

SKULL.

The general form of the skull (pl. 26) in the Rancho La Brea specimen is remarkably similar to that in the Recent African lion and to the cave lion of the European Quaternary. The principal peculiarity noticeable in the broader outlines of the skull is seen in the width of the muzzle compared with the basal length. The breadth of the skull across the zygomatic arches, and also across the upper jaws measured through the superior sectorials is, compared with the basal length, about 5 per cent. less than in a specimen of the African lion in the University collections; while the transverse diameter of the muzzle measured over the narrowest point opposite the diastema is about 5 per cent. greater than in the African lion.

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The widening of the muzzle is probably not due to vertical compression; on the contrary the position of the nasal bones indicates a slight lateral flattening.

In its superior outlines the skull approaches the lion more closely than the tiger. The planes of the frontal and nasal regions seem to have been nearly identical, and the angle which the nasal region makes with the superior line of the sagittal crest is smaller than in the tiger or in the puma. A considerable portion of the frontal region has been crushed and corroded, but as nearly as can be determined, it was originally nearly flat, rather than convex as in the tiger.

The sagittal crest shows about the same degree of development as in the African lion, and the superior line of the crest is nearly straight as in that form.

The brain case is somewhat smaller than in either the lion or the tiger.

In the *facial region,* the anterior narial opening as nearly as can be determined is not materially different from that of the African lion. The form and relations of the nasal elements posteriorly can unfortunately not be seen, owing to corrosion of the skull at this point. The frontal process of the left maxillary, which is well preserved, is rather broadly truncated posteriorly, which probably indicates that the terminations of the nasals, frontals and maxillaries in this region had much the same arrangement as in the tiger.

The *occiput* shows a rather marked narrowing immediately above the mastoid region, due in a large measure to the reduction of the lambdoidal ridges on each side just above the level of the upper side of the foramen magnum. The middle region of the occiput is marked by a sharper ridge than the corresponding median elevation of this region in the lion. In the tiger this region is generally more evenly rounded than in the lion.

The region of the *basioccipital* (fig. 1) is flatter in the space between the auditory bullae than in the lion, and on both sides the greatly roughened area for the attachment of the longus capitis is situated nearer the posterior lacerated foramen than in the lion or tiger. The median tubercle for attachment of the constrictor pharyngis superior, which sometimes appears on the

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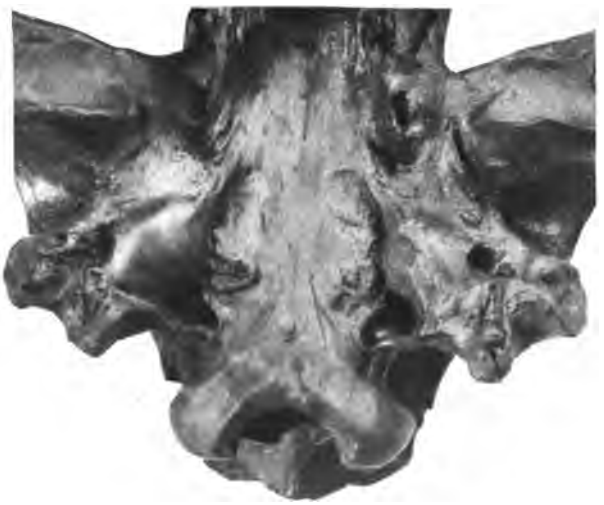

Fig. 1.—*Felis atrox*, variety *bebbi*. Basicranial region, no. 14001, × .45. From the Quaternary of Rancho La Brea.

Fig. 2.—*Felis atrox*, variety *bebbi*. Mandible, no. 14001, × ⅖. From the Quaternary of Rancho La Brea. The angular process is incomplete on this ramus.

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inferior side of the basioccipital and basisphenoid in the lion, is absent in this specimen, as it is in *F. spelaea* according to Dawkins and Sanford.

The *auditory bullae* are much smaller than in either the lion or the tiger, and are smaller than the bullae of any modern feline known to the writer. The entotympanic portion is much less inflated than in the lion. The ectotympanic region is much flattened, and is quite distinctly set off from the entotympanic portion. The anterior spine of the ectotympanic region extends farther forward than the anterior extension of the entotympanic portion, and reaches forward over the base of the zygomatic arch to a point a very short distance behind the middle of the glenoid fossa. The space between the mastoid and postglenoid processes, and opposite the external auditory meatus, is somewhat wider than in the lion.

The external auditory meatus is situated relatively far out from the median line of the skull, the portion of the opening nearest the median line being laterad of the inner side of the stylomastoid foramen, as well as considerably farther out from the median line than the inner end of the postglenoid process.

The paroccipital process is relatively prominent, owing largely to the reduction in size of the auditory bulla.

The *lower jaw* in this species (fig. 2) is slightly heavier than that of the Recent lion and tiger specimens available to the writer, but is apparently not more massive than in some specimens of the European spelaean form. The symphyseal region is somewhat broader and more massive inferiorly than in the lion. This region is, however, covered in part with a rough growth of bone which is more pronounced on the right ramus, and may be due partly to age and partly to unusual conditions existing only in this individual. In one of the specimens of *F. spelaea* figured by Dawkins and Sanford[2] the symphysis is nearly as heavy as in the specimen from Rancho La Brea.

The inferior margin of the jaw is concave as in the tiger, owing to the prominence of the symphyseal region and of the angle. The most prominent portion of the middle region of the

[2] British Pleistocene Mammalia, pl. 1, fig. 1.

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inferior border corresponding to the "ramal process" of Dawkins and Sanford is below the anterior lobe of M_1. The masseteric fossa is very deep, and its extreme anterior border reaches forward to a point opposite the middle of the inferior carnassial. The inferior border of the anterior portion of the masseteric fossa is marked by a sharp upward twist occurring just below the deepest portion of the fossa as in one of the specimens of *F. spelaea* figured by Dawkins and Sanford.[3]

The coronoid process is extraordinarily large and high. The superior portion swings backward somewhat as in the tiger, so that the posterior extremity extends behind the condyle.

The form of the angle is intermediate between that of the lion and the tiger; as it projects inferiorly more than in the lion, and less than in the tiger posteriorly.

Some of the *foramina* show features which seem to be characteristic.

The infraorbital foramina are rather narrowly oval as in the tiger, and are relatively smaller than in the lion.

In the palatine region there is a slight but noticeable peculiarity in the situation of the posterior palatine foramina. The posterior borders of these foramina in this specimen reach back to a point behind the superior molars. In the lion and tiger they are situated somewhat farther forward.

In the lateral region of the skull the foramen rotundum is separated from the sphenoidal fissure by a much thinner bony septum than in the lion, and the space separating this foramen from the foramen ovale seems comparatively wide.

In the basicranial region (fig. 1) the stylomastoid foramen is not situated farther out from the median plane of the skull than is the median or innermost portion of the inferior border of the auditory meatus. In the lion and tiger the stylomastoid foramen is situated relatively much farther from the median plane.

The condylar foramen is in this specimen set relatively far back so that on the left side of the skull it can scarcely be said to be included in the opening of the posterior lacerated foramen.

[3] British Pleistocene Mammalia, pl. 1, fig. 1.

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MEASUREMENTS OF SKULL.

Length from anterior side of premaxillary to posterior side of occipital condyles	395. mm.
Greatest length from anterior side of premaxillary to inion	438.5
Greatest width of zygomatic arches	281.
Least width across muzzle behind superior canines	136.
Width between outer sides of alveolar margins of superior carnassials	139.
Length from a line drawn between the postorbital processes of the frontals to the extreme occipital protuberance	197.
Distance from upper end of foramen magnum to the posterior end of sagittal crest	88.
Length of left ramus of mandible from extreme anterior end to posterior side of condyle	291.5
Length of mandible from anterior side of canine at alveolar border to posterior side of condyle	289.5
Height of lower jaw below protoconid of P_4	55.
Height of lower jaw below protoconid of P_4 in *F. atrox*, type specimen	55.
Thickness of lower jaw below protoconid of P_4	30.8

DENTITION.

Superior Dentition.—The upper teeth are unfortunately considerably worn and broken, so that only P^3 remains absolutely intact. I^3, P^2, and M^1 had disappeared before the specimen was discovered.

Fig. 3.—*Felis atrox*, variety *bebbi*. Right superior carnassial; *a*, outer side; *b*, occlusal view. No. 12501, natural size. From the Quaternary of Rancho La Brea.

The superior canines are unfortunately represented only by the broken basal portions. They are relatively large compared with the anteroposterior diameter of the cheek teeth and compared with the length of the skull. A number of detached superior canines in the collection are considerably smaller than that of no. 14001, but may represent another species.

The form of P^3 resembles that of the modern African lion excepting in the somewhat greater elongation of the cusps in the lion, and in the slightly larger size of the posterior basal

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tubercle in the Rancho La Brea specimen. The crown of this tooth is generally somewhat lower than in the lion, and in *F. spelaea*, and in this respect resembles the tiger.

Both superior carnassials are considerably broken on this specimen, but the form is well shown (fig. 3) on a loose tooth (no. 12501) obtained in the same deposit. This tooth is about comparable to that of the Recent tiger, excepting that the antero-external prominence in front of the protostyle is not as well developed as in the tiger, and the crown is not quite as low.

M^1 seems to have been distinctly two-rooted on one side of the skull, and the roots were nearly separated on the other side.

Inferior Dentition.—The elements of the inferior cheek tooth dentition of the specimen have fortunately been preserved intact. The inferior canines and all of the incisors but the left I_3 have disappeared.

The space occupied by the inferior incisors is relatively small, being only a little greater than in a Recent African lion skull of much smaller size. The roots of the incisors remaining stand in a line which is bowed backward rather sharply compared with the slightly curved transverse line of the incisors in the lion and tiger.

The inferior canines have a greater anteroposterior diameter compared with that of the inferior carnassial than in the lion, but are smaller in comparison with the upper canines.

The diastema is relatively a little shorter than in the Recent lion and tiger, but is not as short as in one of the specimens of *F. spelaea* figured by Dawkins and Sanford.[4]

In P_3 the postero-internal portion of the cingulum is more strongly swollen laterally than in the lion and tiger. P_4 resembles quite closely the form of this tooth in the African lion, excepting that the anterior and posterior cusps are perhaps a little more compressed laterally and are less acute. The protoconid is approximately triangular in cross-section, the inner angle of the triangle extending down to the cingulum as a rather prominent ridge.

M_1 corresponds in relative size and proportions quite closely

[4] British Pleistocene Mammalia, pl. 1.

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to the inferior carnassial of the African lion. It possesses however a well-developed heel and a minute cusp corresponding to the metaconid. Although the paraconid blade is somewhat worn it seems to show evidence that its anterior margin sloped backward more strongly than the nearly vertical anterior border of this portion of the tooth as it may appear in the African lion.

MEASUREMENTS OF DENTITION.

	No. 14001, Rancho La Brea specimen	*F. atrox*, type specimen	*F. leo.*
Length, anterior side of superior canine at alveolar margin to posterior side of P^4	134.5 mm.		98.
Length, anterior side P^2 to posterior side P^4	91.5		67.5
Width, from median side I^1 to lateral side I^3	28.		24.
Superior canine, anteroposterior diameter at alveolar margin	42.3		22.5
Superior canine, transverse diameter at alveolar margin	28.7		16.3
P^2, anteroposterior diameter of alveolus	10.		9.6
P^3, greatest anteroposterior diameter	29.		23.
P^3, greatest transverse diameter	14.6		11.6
P^4, greatest anteroposterior diameter	43.		32.
P^4, greatest transverse diameter across deuterocone	21.5		16.3
P^4, greatest anteroposterior diameter of protostyle	10.		7.
Width between medial borders of alveoli of inferior canines	29.5		25.6
Inferior canine, anteroposterior diameter of alveolus	39.3	33.	23.2
Inferior canine, transverse diameter of alveolus	23.5	20.8	15.2
Length, anterior side of canine at alveolar border to posterior side of M_1	156.8	162.	115.
Length of inferior cheek tooth series	86.7	86.5	64.6
P_3, greatest anteroposterior diameter	20.5	21.3	18.2
P_3, greatest transverse diameter	11.5		10.
P_4, greatest anteroposterior diameter	32.2	31.	23.8
P_4, greatest transverse diameter	16.5		13.5
M_1, greatest anteroposterior diameter	34.	32.	24.5
M_1, greatest transverse diameter	16.8		12.5
M_1, greatest anteroposterior diameter of paraconid blade	16.		11.8

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DIAGNOSTIC CHARACTERS.

Felis atrox Leidy, variety *bebbi.*

Felis atrox, Leidy, Am. Philos. Soc., Trans. New Ser., vol. 10, p. 319.

Type specimen of Mississippi form Col. Acad. Nat. Sc. Philad. Obtained in beds of presumable Quaternary age near Natchez, Mississippi. *Bebbi* form based on specimen 14001, Univ. Calif. Col. Vert. Palae., from the Quaternary of Rancho La Brea, California.

Muzzle very wide compared with the length of the skull. Postorbital processes of the frontal relatively far back. Brain case small. Auditory bullae small. Anterior spine of ectotympanic region extending much farther forward than entotympanic portion. Occiput high and narrow.

Coronoid process of mandible high, wide, and near medial end of condyle. Masseteric fossa very deep and showing a marked excavation as far forward as the middle of the inferior carnassial. Symphyseal region wide inferiorly (possibly an age or individual character). Anterior outline of symphyseal region more nearly normal to the inferior line of the mandible than in the lion or tiger. Condyles set low with reference to alveolar margin. Angle produced inferiorly somewhat farther than in the lion and tiger.

Infraorbital foramen smaller than in the lion or tiger, and situated a little farther back with reference to the P^4. Condylar foramen tending to be separated from posterior lacerated foramen on one side of the skull.

Canines relatively large, and the incisors small or set in a relatively narrow space. M^1 two-rooted. Inferior carnassial with metaconid, and with a well-marked heel developed on the cingulum. Protoconid of P_3 and of P_4 nearly triangular in horizontal cross-section. Inner ridge of the protoconid of P_4 relatively prominent at the base.

Individuals of this species of large size.

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AFFINITIES.

Relation to Felis atrox Leidy.—The lower jaw of the Rancho La Brea specimen approaches very closely in measurements the peculiar feline jaw from Natchez, Mississippi, which served as Leidy's type of *Felis atrox*. Leidy's original specimen unfortunately consisted of only a half of a lower jaw with the cheek teeth and the canine. The comparable dimensions are surprisingly close, particularly in the case of the cheek teeth, as is shown in the table of measurements (p. 300). The cheek teeth are similar in the lack of elevation of the cusps, and in the form of the cusps of P_4. The principal differences are found in the slightly longer anteroposterior diameter of the canine, in the greater development of the anterior basal tubercle of P_3, the shorter diastema, and possibly the greater development of the antero-inferior portion of the symphyseal region, in the Rancho La Brea specimen. Slight differences may also exist in the reduction of the posterior basal tubercles of M_1 in the type specimen. This character is, however, always more or less variable.

Mr. Witmer Stone, who has kindly examined Leidy's type for me, finds a slight indication of an interior basal tubercle on P_3 of the type, though it is not shown in Leidy's figure. This character is more or less variable in the lion.

The form of the mandible is not certainly to be depended upon for specific diagnosis, as the type specimen was covered with a thick ferruginous coating, which may be supposed to have disguised its form somewhat. The marked prominence represented on the inferior border of the jaw below the anterior end of P_4 in Leidy's figure, and considered by Dawkins and Sanford[5] as a possible ramal process, is probably to be considered as principally an irregularity of the ferruginous coating of the jaw. Mr. Witmer Stone, who examined the type with reference to this feature, states that "it has been much exaggerated in the figure, or has been removed since." Mr. Stone believes that it was without question part of the matrix.

The form of the symphyseal region in the Rancho La Brea

[5] British Pleistocene Mammalia, part 3, p. 161.

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specimen is somewhat different from that in the type, in which the antero-inferior region is gently rounded, rather than markedly angular. Variation of this nature may be due in part to difference in age. A considerable irregularity in the roughened surface of the bone in the antero-inferior portion of the symphysis in the Rancho La Brea specimen is possibly in part an individual peculiarity.

While there seems little doubt that the Rancho La Brea specimen is specifically identical with *Felis atrox* Leidy, the slight differences in size of canine, form of P_3, length of diastema, and form of the symphyseal region of the jaw make it desirable to refer to this type as the *bebbi* form, in contrast to the typical specimen.

Relation to Felis imperialis Leidy.—The type of Leidy's *Felis imperialis*[6] was obtained by Dr. Lorenzo G. Yates in a gravel deposit at Livermore Valley, California. In the same beds there were also obtained remains of *Bison latifrons, Auchenia hesterna, Elephas, Equus,* and *Canis indianensis.* This collection taken as a whole indicates the Quaternary age of the deposit. There is, however, no definite statement as to how closely the specimens represented in the collection were associated.

The type specimen consisted of an upper jaw fragment containing P^3, and showing the alveoli of P^2 and the canine. It is considerably smaller than the Rancho La Brea specimen, as is indicated by the following table of comparative measurements:

	F. imperialis, type	Rancho La Brea specimen
Length, from posterior side of canine alveolus to posterior side of P^3	45.4	54.
P^3, anteroposterior diameter	23.7	29.
P^3, height measured from cingulum to apex of protocone	14.8	15.5
Diameter of canine alveolus	29.2	42.3

A perfectly preserved upper canine in the University collections from Rancho La Brea agrees almost exactly in size with that of the type of *F. imperialis.*

[6] Leidy, J., Proc. Acad. Nat. Sc. Philad., 1873, p. 259.

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The fragmentary nature of the type of *F. imperialis* makes it nearly impossible to determine certainly whether it is to be considered identical with *F. atrox*. The difference in size, amounting to about one-fifth, is probably not sufficient to exclude it from *F. atrox*. The only other character available for comparison is found in the form of P^3. This tooth is according to Leidy's figure[1] relatively high, measured from the cingulum to the apex of the protocone. In the corresponding tooth of the Rancho La Brea specimen of *F. atrox* the height is relatively less, or the tooth relatively longer anteroposteriorly. In the *F. imperialis* specimen the posterior cusp is higher with relation to the posterior basal tubercle. The high form of P^3 is rather characteristic of the recent puma, while the lower form is seen in the tiger. P^3 of the lion is somewhat higher than in the tiger. Some doubt must exist as to whether this character is definite enough to warrant the separation of the *F. imperialis* specimen as a distinct species, even if the tooth in question is represented with absolute accuracy in Leidy's figure.

Leidy suggested that *F. imperialis* might be found to represent a young individual of the *F. atrox* type, and the range of size in the specimens available from Rancho La Brea might be considered as evidence pointing in this direction.

A milk carnassial of a large cat of the *Felis* type described by Bovard[2] from the Quaternary of Potter Creek Cave, was recognized as possibly representing *Felis imperialis*. This specimen, as shown by the table of measurements below, corresponds to the Recent African lion in dimensions. It represents an animal nearer to the size of the type of *F. imperialis* than to that of the Rancho La Brea specimen.

MEASUREMENTS OF SUPERIOR MILK CARNASSIALS.

	No. 3825, Potter Creek Cave	Recent African Lion	Puma
Anteroposterior diameter	24.6 mm.	24.3	16.
Transverse diameter	8.2	8.	4.6

[1] Leidy, J., U. S. Geol. Surv. Terrs., vol. 1, 1873, pl. 31, fig. 3.

[2] Bovard, J. F., Univ. Calif. Publ. Geol., vol. 5, p. 163.

Second edition, issued September 3, 1909.
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EXPLANATION OF PLATE 26.

Felis atrox, varięty *bebbi*.

Skull, no. 14001, a little more than one-third natural size (× .367). From the Quaternary of Rancho La Brea.

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UNIVERSITY OF CALIFORNIA PUBLICATIONS

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Vol. 5, No. 21, pp. 305–317 ANDREW C. LAWSON, Editor

TERATORNIS

A NEW AVIAN GENUS

FROM RANCHO LA BREA

BY

LOYE HOLMES MILLER.

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INTRODUCTION.

Among many interesting forms of vertebrates taken from the Quaternary asphalt of the Rancho La Brea beds in Southern California, there have appeared several specimens of a very large bird which shows such marked divergence from Recent forms as to necessitate the establishment of a new genus. Though the form appears raptorial, its final assignment to any of the existing families is held in reserve at present, as some degree of uncertainty regarding its body skeleton makes conservatism appear the preferable chance of error. Four cranial fragments of the species have been taken in one small excavation. One found by Dr. William Bebb of Los Angeles was kindly loaned to the author; a second, discovered by Mr. Eugene Fischer, was presented to the University of California. The other two, including the most complete specimen, were taken during the University of California excavations.

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Associated with the remains of the new form in the Rancho La Brea beds, there occur a number of characteristic mammalian forms of these deposits; for example, *Canis indianensis; Canis,* n. sp.; *Smilodon* (?) *californicus; Bison antiquus; Elephas,* sp.; *Paramylodon nebrascensis; Equus pacificus.*

According to Merriam[1] this "fauna as a whole cannot be considered as other than Quaternary, although the particular division of that system represented is not as yet determined."

A large number of specimens representing many avian species have been taken from the Rancho La Brea beds. The entire collection of the University of California was placed at the author's disposal and every possible courtesy shown him by Professor John C. Merriam. A preliminary examination was made of this collection together with material from the same source in the collections of Dr. William Bebb and Dr. F. C. Clark, both of Los Angeles. Mr. F. A. Lucas very kindly reviewed the writer's manuscript before publication.

Thus far the following avian species have been determined from the Rancho La Brea beds. *Gymnogyps californianus, Cathartes aura, Catharista occidentalis,*[2] *Aquila chrysaëtos, Circus hudsonius, Buteo borealis, Aluco pratincola, Asio wilsonianus, A. accipitrinus, Bubo virginianus, Speotyto cunicularia, Bernicla canadensis, Ardea herodias, Pavo californicus, Corvus corax.* Several accipitrine forms, a small *Polyborus,* a large ciconid, a small crane, a pheasant, and one or two passerines remain yet in doubt.

The large preponderance of raptorial species will at once be noted in this list. If, however, the number of individuals be taken into consideration, the preponderance becomes overwhelming. For example, there appear in the part of the University collection thus far examined no less than thirty-three individuals of the Golden Eagle. In the same mass of material, the non-predaceous species Great Blue Heron, American Raven and Can-

[1] Univ. Calif. Publ. Geol., vol. 5, p. 291.

[2] Assignment of the California form of *Catharista* to distinct specific rank is based on a comparison of the Recent *Catharista atrata* with a series of twenty-one partial skeletons of the Rancho La Brea form. For this new species the name *Catharista occidentalis* is proposed. Type specimen no. 12509, Univ. Calif. Col. Vert. Palae. Body larger as judged by the skull, sternum and pelvis; femur longer and heavier (107%); tarsus shorter (94%) but stouter (109%); foot wider (116%); humerus longer (108%).

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ada Goose are represented by but one specimen each. A similar relation between predatory and non-predatory species is noted by Professor Merriam[3] among the mammalia from this formation.

Numerous writers on the Golden Eagle as it exists today have commented upon the carrion habit of the species. Its abundant occurrence in the asphalt trap of Rancho La Brea bears proof of the long standing of this habit of preying upon either dead or disabled creatures. The specimens taken average large and possibly represent birds in old age. The left tarsus of one individual shows an abundant exostosis due to some diseased condition which caused the loss of the entire foot. Merriam noted among mammals entrapped in the asphalt a large preponderance of young individuals, accompanied in case of carnivores by a large number of individuals with worn or broken teeth. He ascribes these conditions to the inexperience of the young or to the extremity of the aged. Possibly among predaceous birds, cared for in youth and taught by instinct to seek an active prey not discerned by the sense of smell, it was largely the old or otherwise disabled individuals which resorted to this ignoble feast.

DIAGNOSTIC CHARACTERS.

Teratornis merriami, n. gen. and sp.

Type specimen no. 12101, Univ. Calif. Col. Vert. Palae. Skull as far forward as the lachrymals. Cerebellar region much reduced. Auditory prominences developed outward and backward beyond the posterior extremity of the brain case. Foramen magnum deeper than wide. Basipterygoid processes well developed. Lachrymals entirely fused with frontals and with ectethmoids. In co-type no. 12507, beak hooked, very deep and greatly compressed.

SKULL.

On viewing the skull from below at right angles to the basisphenoidal rostrum (fig. 1), two very striking characters are evident. The cerebellar region is greatly reduced and the post-auditory prominences are thrust backward and outward until

[3] Merriam, J. C., Science, N. S., vol. 24, p. 248, 1906.

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their ventro-lateral angles form the posterior extremities of the skull. The rear profile becomes concave in general, with the median portion of the arc slightly interrupted by a gentle convexity. The foramen magnum seems unique among known Raptores. It lies in a plane facing as much backward as downward and is decidedly deeper than wide. It has a sagittal diameter of 14.3 mm., but measures only 11 mm. transversely across its center. Toward the condyle it widens out slightly, so that it appears bluntly pear-shaped in outline. The occipital condyle

1 2

Figs. 1 and 2, *Teratornis merriami*. Fig. 1, Skull no. 12101 from below, × ½. Fig. 2, Skull no. 12101 from the rear, × ½. *A*, postauditory process; *B*, basisphenoidal process; *C*, cerebellar protuberance; *F*, postfrontal process; *l*, descending process of lachrymal; *p*, basipterygoid process.

shows no peculiarity except possibly less tendency to form a constricted neck than in most raptorial forms. Just forward of the condyle, however, the basioccipital is excavated in two very deep, rounded pits separated from each other by a low median ridge. In front of this depression the basisphenoid rises in an abrupt transverse ridge ending laterally in a pair of high basisphenoidal processes. The whole region immediately anterior to the condyle thus presents a very rugged topography. The basipterygoid processes are well-marked fungiform structures placed far back upon the sphenoidal rostrum. This rostrum is intact, and the interorbital septum is imperforate except at the optic foramen (fig. 4).

Viewed from the rear (fig. 2) the dome of the skull shows a

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very flat, regular curve, gradually increasing laterally as the postfrontal processes are deflected more abruptly at their ends. There is no tendency toward the longitudinal furrowing in the region of the cerebrum that is noticeable in many recent accipitrines.

The occipital region is marked by a well-defined transverse ridge passing across from one postauditory prominence to the other and curving gently upward to form the dorsal border of the foramen magnum. This transverse ridge is the angle of intersection of two slightly concave surfaces, a postero-dorsal and a postero-ventral slope. The ventral surface, trending forward and downward, includes the plane of the foramen magnum and a nearly smooth ex-occipital surface on either side of it. The whole postero-ventral surface is remarkably uniform in its concavity and almost unbroken, except as interrupted near its center by the abrupt rise of the occipital condyle and by the basioccipital depressions. Above the transverse ridge the postero-dorsal area slopes forward and upward to a limiting, transverse intermuscular ridge near the dorsal profile of the skull. Across its middle passes a second transverse intermuscular ridge and down its median sagittal line an abrupt vertical crest, the cerebellar protuberance. The lateral terminations of the upper limiting crest are almost confluent with the temporal crests. Thus the whole posterior aspect of the skull must have been hidden by the powerful musculature of the head and neck.

From above (fig. 3), the great flatness of the skull is again evident, although its roof is gently convex on the whole in any vertical section. Even in the region of the lachrymals the median line is not depressed below the orbital borders. A very slight downward tendency is shown at the region where the nasals begin, but beyond this point the parts are wanting. There is positive indication, however, of a high "bridge of the nose" as in Cathartidae and in contrast with falconids (figs. 9, 10, 11).

The masseteric depressions lie largely upon the top of the skull in a plane approaching the horizontal (fig. 3). In Cathartidae and Falconidae these areas lie in the lateral and posterior aspects of the skull in a more nearly vertical plane.

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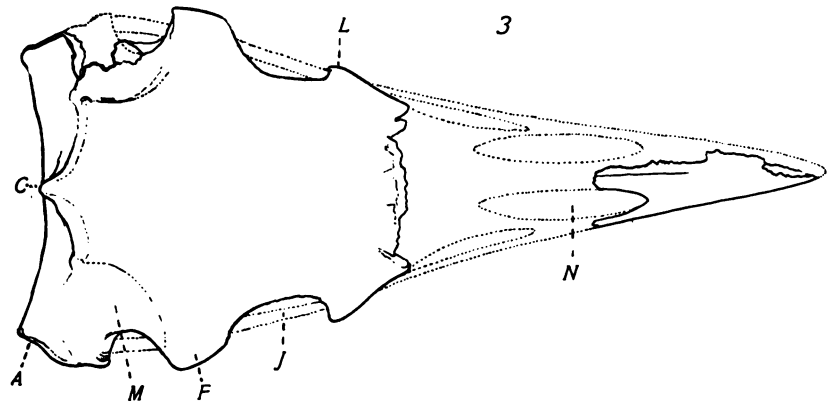
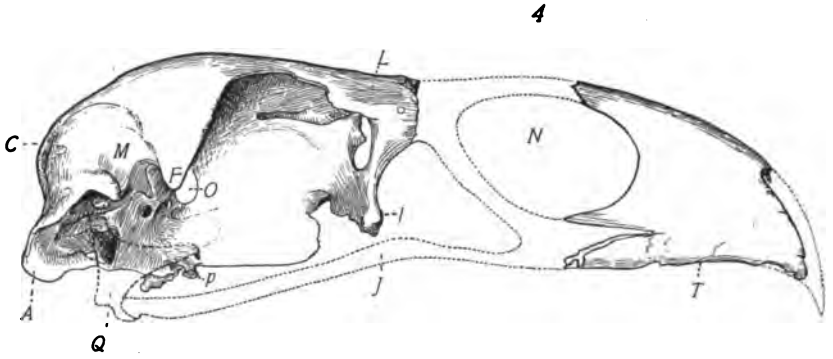
From the side of the skull, with the sphenoidal rostrum in a horizontal plane, the highest point of the skull dome is seen to be in front of the posterior border of the orbit; and the slope from this point, both backward and forward, is very gradual. The skulls of recent falconids and cathartids examined





Figs. 3 and 4. *Teratornis merriami.* Reconstruction of the skull based upon accurate drawings of cranial fragment 12001 and beak fragment 12507; × ½ . Missing parts are represented in dotted lines. Fig. 3, skull from above; fig. 4, skull from right side. *A*, postauditory prominence; *C*, cerebellar protuberance; *F*, postfrontal process; *J*, jugal bar; *L*, orbital portion of lachrymal; *l*, descending lamella of lachrymal; *M*, masseteric depression; *N*, nostril; *O*, optic foramen; *p*, basipterygoid process; *Q*, quadrate; *T*, tomial edge.

show the highest point of the skull to be farther back and in a much more pronounced curve. The descending process of the lachrymal does not reach the level of the sphenoidal rostrum (fig. 4). This condition in Cathartidae gives rise to an upward

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flexure of the quadratojugal bar at an angle with the tomia of the beak. Possibly the same condition produced a like result in the form under discussion (figs. 9, 10, 11). As before stated, the beak of the type specimen is entirely wanting. The description given below is of a distal fragment (fig. 4), believed by Mr. E. J. Fischer, the University collector, to be part of specimen no. 12507, a skull of *Teratornis* almost identical in size with the type specimen. This specimen was shattered through the lachrymal and nasal region while concealed in the matrix. The cranial portion and the beak-tip alone were preserved. The affinities evident from the structure of this fragment are in perfect harmony with those displayed by the cranial fragment and by the type specimen. In the beak, though the major portion of the left side is wanting, enough of the ridge of the culmen is present to show the extreme degree of compression (fig. 5). The median septum is intact, likewise more than half the roof of the mouth in the premaxillary region.

Fig. 5, *Teratornis merriami.* Beak fragment 12507 seen from directly in front, × ½. *Op*, opening from beak cavity into the mouth.

While the general appearance of the beak is decidedly aquiline, its structure is vulture-like in the main. There is no osseous internareal septum. The great open nostrils both communicate, as in *Cathartes,* with the whole inner cavity of the beak-tip and with the mouth cavity. At a point half way between the anterior margin of the nostril and the end of the beak, the beak cavity is divided by the ossified median septum into two high and very narrow recesses. The roof of the mouth in this region is but slightly arched, in fact almost flat, as in the falconids, and not at all like the high vaulted beaks of *Cathartes* and *Gymnogyps.* The tomial edge also resembles falconids in its straightness just posterior to the hook (fig. 4).

The degree to which the beak is hooked is not exactly determinable. The amount broken from the tip is very slight, and it would seem, from careful examination of the region, that the amount of overhang might have equaled that found in the eagles (fig. 4).

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MEASUREMENTS OF SKULL.

Width across postero-ventral points of postauditory prominences	70.	mm.
Width across postorbital processes	94.	
Width through masseteric notch	69.	
Least interorbital width of frontal region	55.3	
Highest point of crown above sphenoidal rostrum	57.2	
Depth of foramen magnum	14.3	
Greatest transverse diameter of foramen magnum	12.4	
Sagittal diameter of occipital condyle	7.	
Transverse diameter of occipital condyle	8.2	
Length from nuchal tubercle to anterior margin of lachrymal	99.3	
Diameter of orbit from postfrontal process to posterior point of lachrymal	45.	
Diameter of orbit from postfrontal process to ventral point of lachrymal	52.5	

PECTORAL ARCH.

There are in the University collection the coracoids, sternum and furcula of a raptorial bird of gigantic size which probably represent *Teratornis* and are therefore provisionally described in this connection.

The sternum (no 11190) shows three points of divergence from the Recent raptorial type (figs. 6 and 7). First: its length is greatly reduced until it becomes less than the extreme breadth. Second: the anterior region is expanded until the manubrium becomes a wide, slightly produced mound, excavated at its summit in an open, gentle curve which separates the coracoidal fossae by a distance of 23 mm. Third: the hyosternal processes are developed forward and outward till the anterior and the lateral margins of the sternum both become strongly concave. Since, however, the rib articulations come to the end of the hyosternal processes, the condition might be more properly considered an excavation of the anterior and the lateral borders by a prolongation of the hyosternal processes.

The rib articulations are but five, a number more cathartid than falconid. The general concavity of the sternum is similar to that of Recent Raptores.

The hyosternal fossae occupy the entire anterior part of the hyosternal processes, but are not prolonged backward along the costal articulations. Owing to the transverse extension of these processes the fossae then become very much extended laterally, but very narrow in their anteroposterior dimensions (fig. 6).

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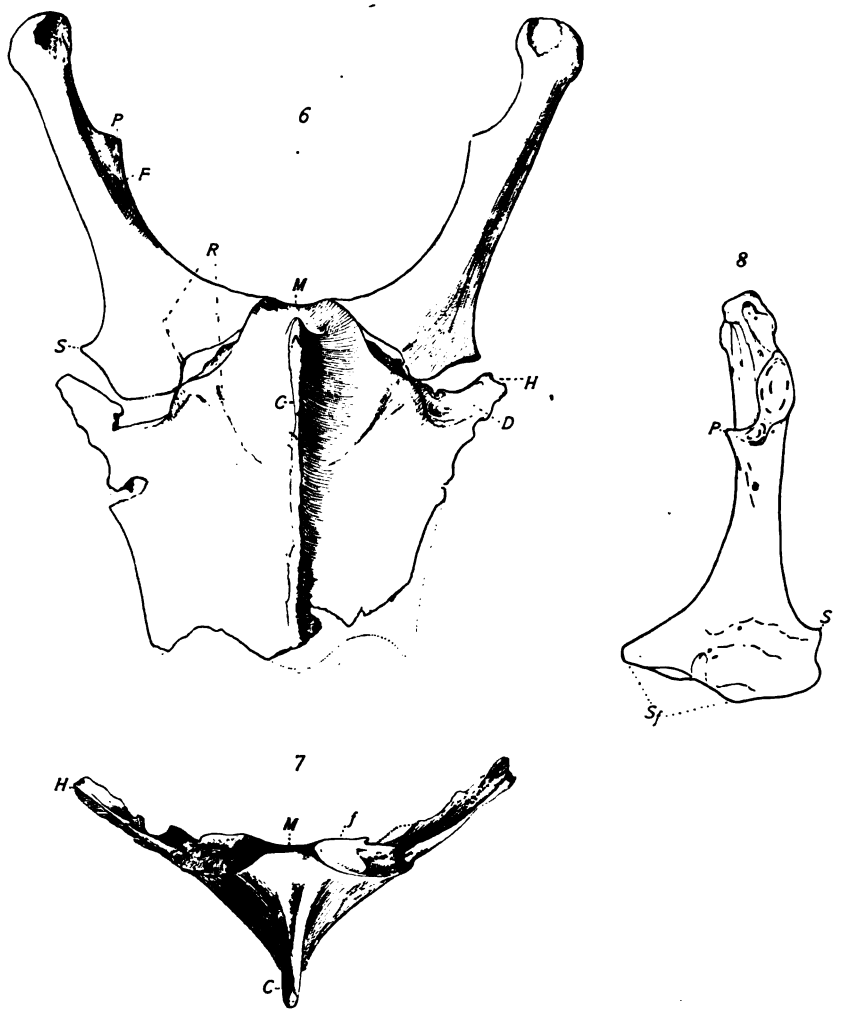

Fig. 6, Sternum and coracoids of *Teratornis merriami* seen from ventral side, × ⅓. *C*, carina; *D*, depression of the hyosternal process; *F*, foramen of the nervus supracoracoideus; *H*, hyosternal process; *M*, manubrium; *P*, praecoracoidal process; *R*, ridge of pectoralis secundus; *S*, sternocoracoidal tubercle.

Fig. 7, *Teratornis merriami*. Sternum no. 11190, seen from the anterior edge, × ⅓. *C*, carina; *f*, coracoidal fossa; *H*, hyosternal process; *M*, manubrium.

Fig. 8, *Teratornis merriami*. Coracoid no. 12511 from dorsal side, × ⅓. *P*, praecoracoidal process; *S*, sternocoracoidal tubercle; *Sf*, sternal facet.

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The fossa of the pectoralis secundus is relatively small on the sternum and, as prolonged upon the coracoid, occupies less than half the width of the ventral face of that bone.

The posterior margin of the sternum as preserved indicates a rather open notch on either side,—a factor of great variability even in the limits of a species at present.

The carina is relatively low as nearly as can be judged. The anterior margin is intact from where it bends upward from the wide manubrial region to the most anterior tubercle of the free carina edge (fig. 7). The anterior margin thus becomes very thick, but this thickness diminishes gradually backward instead of appearing as a pronounced welt upon the anterior end of the keel.

The coracoid and furcula are decidedly cathartid. The coracoid shows a wide sternal end tapering gradually to a comparatively narrow shank (fig. 8). The sternal facet occupies less than two-thirds the total width of this end. The ridge of the pectoralis secundus comes down the coracoid and crosses its sternal facet at a point more than two-thirds the length of the facet from its manubrial limit, but such is the widening of the coracoid base that the fossa of the pectoralis secundus occupies less than half the width of the bone. The hyosternal apophysis is thin and flat, with the sterno-coracoid tubercle but little recurved. On its dorsal aspect the base of the coracoid is comparatively little excavated. Its head region shows striking similarity to that of *Gymnogyps*. The praecoracoidal process is a little less pronounced, thus reducing somewhat the concavity of the axial aspect of the head. The process is pierced by the foramen of the supracoracoid nerve.

The furcula (no. 12508) lacks the distal half of the right clavicle and the scapular tuberosity of the left clavicle. There are numerous pathological exostoses about the distal end of the left clavicle so that the grosser characters alone are to be noted. Considering the great spread of the extremities of the arch, the shaft of the clavicle seems rather more slender than in *Cathartes*. Its cross-section is a little more rounded. The region of symphysis presents practically the same appearance as in *Cathartes*. The angle of divergence of the two clavicles is very much greater

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than is the case in *Cathartes* or in *Gymnogyps*. On the whole these form a group of minor distinctions.

TABLE OF MEASUREMENTS.

Sternum	
Length from manubrial notch	140 mm.
Width across hyosternal processes	177
Width of manubrium between coracoidal facets	17
Coracoid	
Extreme length	162
Greatest width of sternal end	75
Least right and left diameter of shaft	17
Distance from subclavicular process to extremity of head	53
Distance from subclavicular process to axial point of sternal end	101
Furcula	
Middle of symphyseal notch to extreme distal curvature	149
Smallest dorsi-ventral diameter of shaft	10.5
Smallest antero-posterior diameter of shaft	15
Extreme distance between shoulder points with coracoids in place	230

AFFINITIES.

From the characters of the skull alone it becomes difficult to place *Teratornis* in the present scheme of classification. The generally accepted subdivision of the group Raptores includes three families—namely, Falconidae, Cathartidae, and Serpentariidae. The last-named family is represented by the single genus *Serpentarius*. *Teratornis*, if it be considered raptorial, displays characters more or less distinctive of each of these groups, though a preponderance of cathartid affinities is evident. At least one of these, the possession of basipterygoid processes, is shared by *Serpentarius*. The fusion of the lachrymals with the frontals and ectethmoids is strictly cathartid, as is the free communication of the nostrils with the mouth and the beak cavities. The very slight depression of the nasal region, the relative shortness of the descending process of the lachrymals, the smooth contours of the skull dome, the enlarged processes of the basisphenoid, are all cathartid characters. With these features must be reconciled the high, compressed beak, probably strongly hooked, and certainly not excavated on the buccal side at the tip, the almost straight tomial edge, the high and probably short nostril, the large lachrymals,

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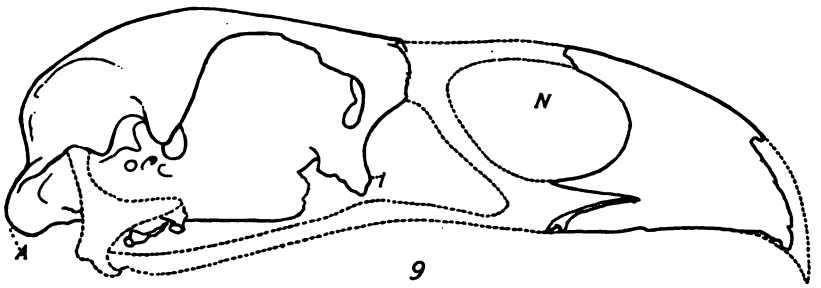

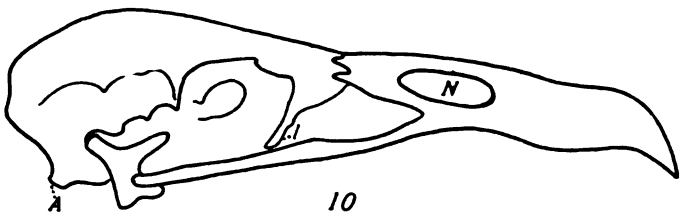

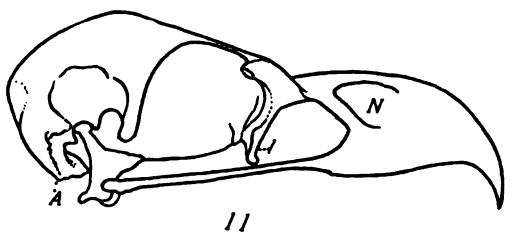

Fig. 9. Reconstructed skull of *Teratornis merriami.*

Fig. 10. Skull of *Gymnogyps californianus,* adapted from Ridgway.

Fig. 11. Skull of *Haliaëtus leucocephalus alascanus,* large female.

Figures one-half natural size. *A,* postauditory process; *l,* descending portion of lachrymal; *N,* nostril.

and the solid interorbital septum, all of which are falconid characteristics. The genus is unique in its combination of characters, in the peculiar configuration of the occipital region, the flatness of the skull, the shape of the foramen magnum, the large size, and, if we accept the association of the other parts described, in the remarkable shape and proportions of the sternum.

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Such a bird in life, judged by the standards of systematic ornithology at present in vogue, would almost necessarily be considered as representing a distinct family, which would naturally be known as the Teratornithidae. That exceedingly important taxonomic point, the character of the lower limb, is still unknown to us. It is hoped that further excavations at Rancho La Brea will better define *Teratornis* in this regard.

The form described in this paper is given its specific name in honor of Professor John C. Merriam of the University of California.

Issued, September 10, 1909.

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BULLETIN OF THE DEPARTMENT OF

GEOLOGY

Vol. 5, No. 22, pp. 319-330 ANDREW C. LAWSON, Editor

THE OCCURRENCE

OF

STREPSICERINE ANTELOPES

IN THE

TERTIARY OF NORTHWESTERN NEVADA

BY

JOHN C. MERRIAM.

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INTRODUCTION.

During the summer of 1909, a palaeontological expedition was organized and financed by Miss Annie M. Alexander for the purpose of collecting mammalian remains in the Tertiary formations of northwestern Nevada, the collections being presented by Miss Alexander to the University of California. The party worked over the region of Virgin Valley, and Thousand Creek, in which a small collection had been obtained by the writer in 1906[1], and also obtained material at a number of localities not heretofore known. The collections brought together represent a

[1] Merriam, J. C., The Occurrence of Middle Tertiary Mammal-Bearing Beds in Northwestern Nevada, Science, n. s., vol. 26, p. 380.

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wide range of mammalian forms, of which a considerable percentage are new. Some of the most interesting material, particularly from the point of view of the student of geographic range and origin of faunas, is that representing a number of antelopes of the strepsicerine or twisted-horned type, known at the present time only in Africa. No representatives of these forms have been known heretofore from the Western Hemisphere, though they were present in Eurasia in middle to late Cenozoic time.

Twelve specimens of horn cores were obtained in the beds at Thousand Creek, including a number of quite different types. The range of form may be due in part to variation in age or possibly in sex, but cannot be attributed entirely to these factors. There appear to be at least two species represented which evidently belong to two quite distinct genera.

ILINGOCEROS[2] ALEXANDRAE, n. gen. and sp.

Type specimen no. 11880, Univ. Calif. Col. Vert. Palae., from late Tertiary beds near Thousand Creek in northern Humboldt County, Nevada. The species is named in honor of Miss Annie M. Alexander, through whose efforts the collections of Tertiary mammals from northwestern Nevada have been obtained and made available for scientific investigation.

Frontals not cavernous at the base of the horn core. Horn cores, situated upon the upper posterior region of the orbits, sloping backward, slightly outward, and tilted upward at an angle of approximately twenty-five degrees from the plane of the frontals above the orbits. Horn cores tending to be circular in cross-section excepting for the presence of two or more well-developed spiral ridges. Principal spiral ridge arising above the postero-superior region of the orbit and swinging backward around the axis at the rate of about one turn in three and one-half inches. Posterior to a strong groove behind the principal ridge a second spiral elevation may be present, and a third may be present in some specimens referred to this genus. Supraorbital foramina present at the anterior side of the base of the horn cores.

[2] Ἴλιγγος, a whirlwind; κέρας, horn.

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The type specimen (figs.1 and 4) consists of the basal portion of a left horn, with a part of the frontal forming the superior portion of the orbit and the brain case.

The frontal region, exclusive of the horn cores, so far as represented on any of the specimens, is almost flat anterior to the base of the horns (fig. 3), and the space between the horns is perfectly even, or without a median ridge. Behind a line

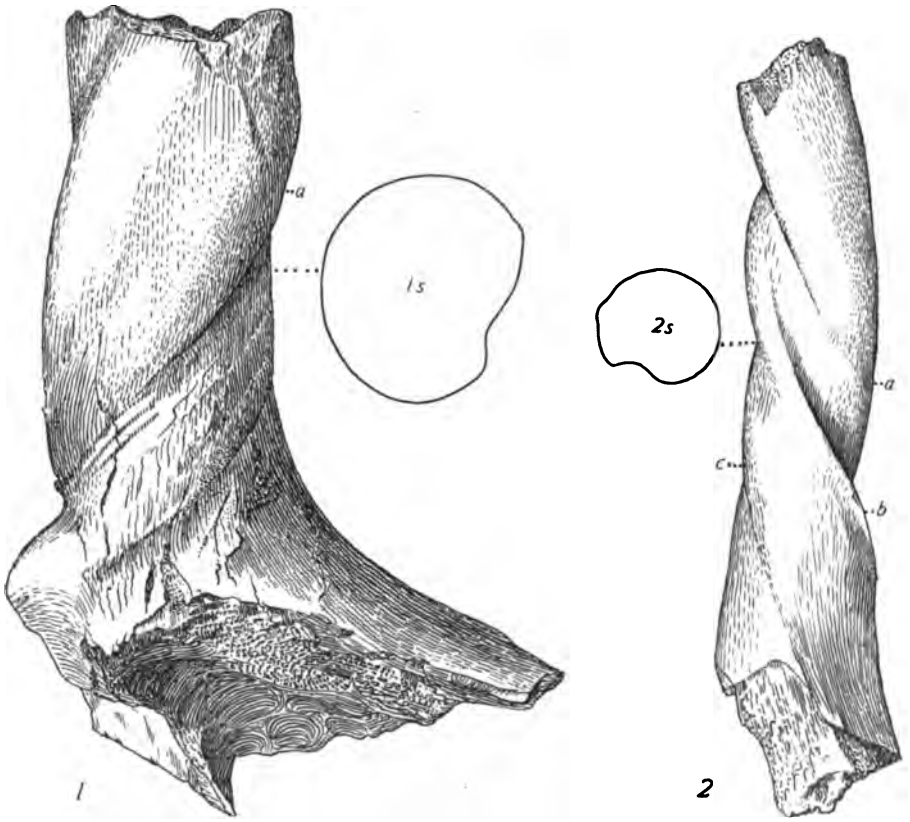

Fig. 1.—*Ilingoceros alexandrae.* Posterior view of base of left horn core; *a*, spiral ridge arising over the postero-superior region of the orbit; *1s*, cross-section of horn core. No. 11880, type specimen, natural size.

Fig. 2.—*Ilingoceros*, form B. Posterior to postero-median view of basal portion of right horn core; *a*, anterior spiral ridge probably corresponding to ridge *a* in figure 1; *b*, median or lateral spiral ridge; *c*, posterior spiral ridge; *2s*, cross-section of horn core. No. 11892, natural size.

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connecting the anterior sides of the bases of the horns the frontals slope backward and downward from the frontal plane anterior to the horns at an angle of about sixty degrees. On those specimens showing the portion of the frontal above the orbits the supraorbital foramina (fig. 3) are situated a little behind the middle of the superior side of the orbit, and just in front of the middle of the base of the horn core. They vary from round to long-elliptical in form.

Fig. 3.—*Ilingoceros*, sp. Frontal region with bases of horn cores. No. 11882. ×½.

The horn arises immediately above the upper posterior region of the orbit (fig. 4), and the middle of its basal portion is situated almost immediately over the postorbital process of the frontal. It slopes backward and slightly outward with a sufficient upward tilt to make an angle of approximately twenty-five degrees with the plane of the frontal above the orbits. In the type specimen a low, rounded ridge which arises from the portion of the horn core base nearest the orbit swings backward over the outer side of the horn, twisting around it at the rate of one complete turn in about three and one-half inches. This ridge grows much stronger as it approaches the posterior side of the horn. In the type specimen it is accompanied by a groove which arises just above the postorbital process of the frontal. A second ridge rises behind this grove so that two distinct spiral ridges are present (fig. 1).

Excepting the notch formed by the groove between the two principal ridges, the cross-section of the horn core in the type specimen tends to be approximately circular, as it is also in a fragment of a horn (no. 11886) quite certainly referable to this species. Judging from the nearly uniform width at the two ends

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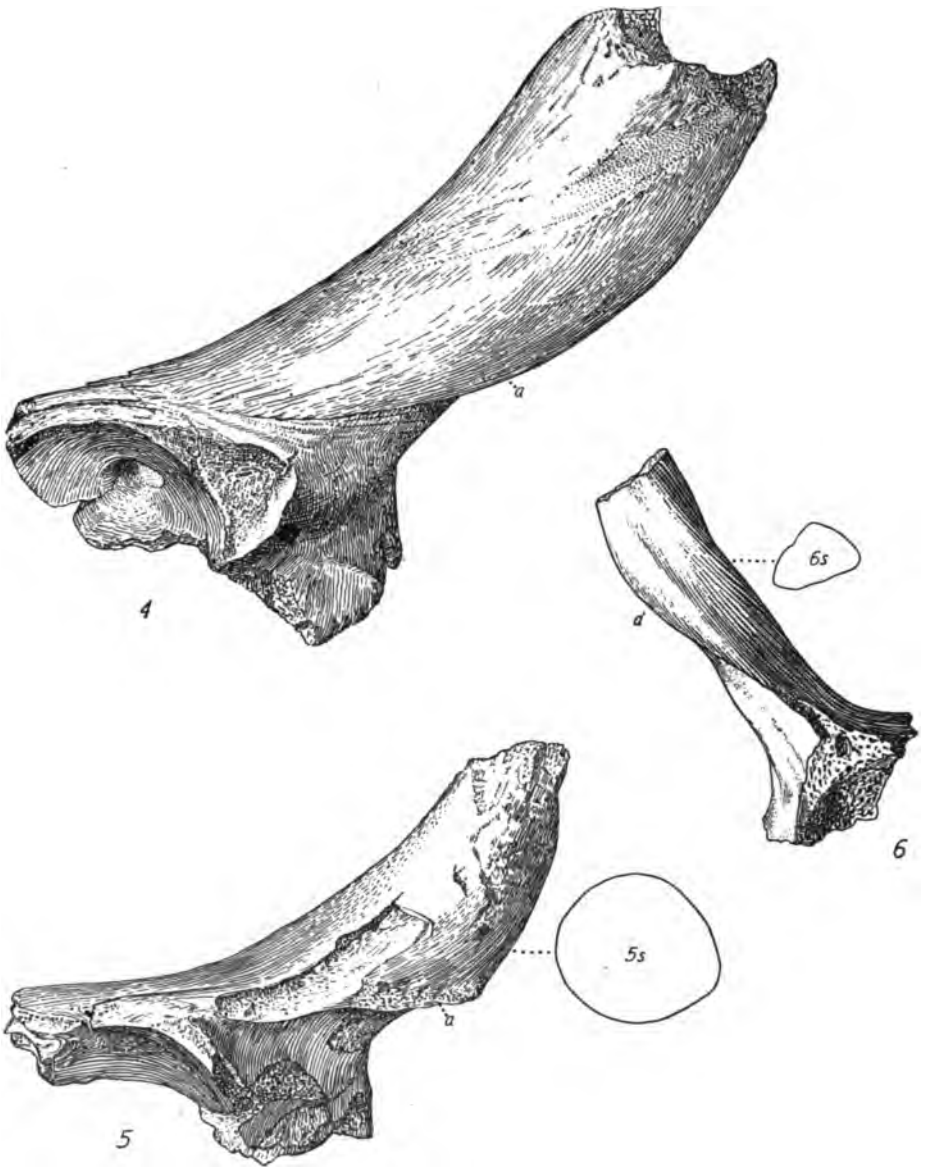

Fig. 4.—*Ilingoceros alexandrae.* Outer side of left horn core and orbital region; *a*, spiral ridge originating over postero-superior region of orbit. No. 11880, type specimen, natural size.

Fig. 5.—*Ilingoceros alexandrae?* Outer side of left horn core and orbital region; *a*, spiral ridge originating over postero-superior region of orbit; *5s*, cross-section of horn core. No. 11894, natural size.

Fig. 6.—*Ilingoceros*, form C. Outer side of right horn core; *a*, spiral ridge originating from postero-superior region of the orbit, and presumably connected with the postorbital process; *6s*, cross-section of horn core. No. 11893, natural size.

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of all of the fragments seen, the horns did not taper rapidly, and tended to be considerably elongated.

The surface of the horn core is comparatively smooth, with almost no pits or roughnesses. The texture is solid, and not spongy as in the true bovine forms. On none of the specimens does there appear to be a distinct line marking the proximal edge of a horny sheath.

In specimen no. 11894 (fig. 5), representing an individual considerably smaller than the type, there is a single strong, acute crest developed, which corresponds to ridge *a* of the type. The general form of the horn is like that of *Ilingoceros*, and it may be referred tentatively to *I. alexandrae*.

In specimen no. 11892 (fig. 2) a horn considerably smaller than the type shows near its base a narrow, sharp ridge with a high, rounded one accompanying it on one side, and a lower one on the other side. The lower accompanying ridge dies out above or unites with the middle one leaving only two prominent ones. Some distance above the base the sharper one becomes less abrupt and more like the other. The sharp median ridge, called ridge *b* (fig. 2), may correspond to a minor crest that arises from the posterior angle of the postorbital process of the frontal in the type of *I. alexandrae*. The principal spiral ridge arising above the orbit in the type specimen may be called ridge *a* (see figs. 1 and 4). It probably corresponds to the ridge to the right of the median elevation shown in fig. 2. The posterior elevation, ridge *c*, on no. 11892 possibly corresponds to the most posterior elevation arising behind the postorbital process in the type.

Another specimen, no. 11899, seems to be quite certainly of the same type as no. 11892. It belongs to an individual of larger size than no. 11892, but is smaller than the type. These specimens may both represent an earlier stage of development of this species than the type specimen. The fragment, specimen no. 11899, is also probably from a part of the horn core somewhat farther above the base than the uppermost part of the horn core as represented in the type. They may both be referred tentatively to this genus as form B, in contrast with the typical form represented in specimen no. 11880 (figs. 1 and 4).

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A very small specimen, no. 11893 (fig. 6), shows a cross-section of the horn core faintly suggesting that of the type of *Sphenophalos nevadanus* described below. In cross-section at the top the long diameter is a little more than twice the short diameter. On this specimen two sharply marked ridges arise at the base of the horn core, and come into positions diametrically opposite each other a short distance above the base. They twist about the core at a rate of about one complete turn in four inches, or at nearly the same rate as in *I. alexandrae*. As yet we have no definite evidence of a spiral twist of the ridges on the horn core of the type of *S. nevadanus*, though a slight turn outward and backward from the upper region of the orbit is suggested. This specimen differs from no. 11894 in that the ridge *a*, which seems to rise just outside the superior openings of the supraorbital foramina as in ridge *a* in the type of *Ilingoceros*, appears to be continuous with the posterior angle of the post-orbital process instead of just above it, and may correspond to ridge *b* in no. 11892, form B. There is farther no suggestion in no. 11894 of a second strong crest opposite ridge *a* as is shown here. From specimen 11892, designated as group B of *Ilingoceros*, this form differs in that the two main crests are near together with a narrow groove between them in group B, while here the main ridges assume positions diametrically opposite each other and the cross-section is narrow.

Specimen 11893 may be referred to *Ilingoceros* tentatively, and designated as form C.

SPHENOPHALOS[3] NEVADANUS, n. gen. and sp.

Type specimen no. 11887, Univ. Cal. Col. Vert. Palae., from late Tertiary beds near Thousand Creek in northern Humboldt County, Nevada.

Frontals not cavernous at the base of the horns. Horns situated on the upper posterior region of the orbits, sloping backward, slightly outward, and tilted upward at an angle between twenty-five and thirty degrees from the plane of the frontals above the orbits. Horn cores flattened in a plane extending

[3] σφήν, wedge; φάλος, horn on a Homeric helmet.

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backward and inward from the orbits. A short distance above the base the horn cores flare or widen slightly in the direction of greatest diameter in cross-section. Outer anterior edge of the horn core arising over the upper posterior region of the orbit, and swinging backward with a suggestion of a twist. Surface of the horn core comparatively smooth, with a few pits or irregularities. Texture of the outer portion of the horn core solid. Supraorbital foramina present in front of the middle of the antero-medial side of the base of the horn cores.

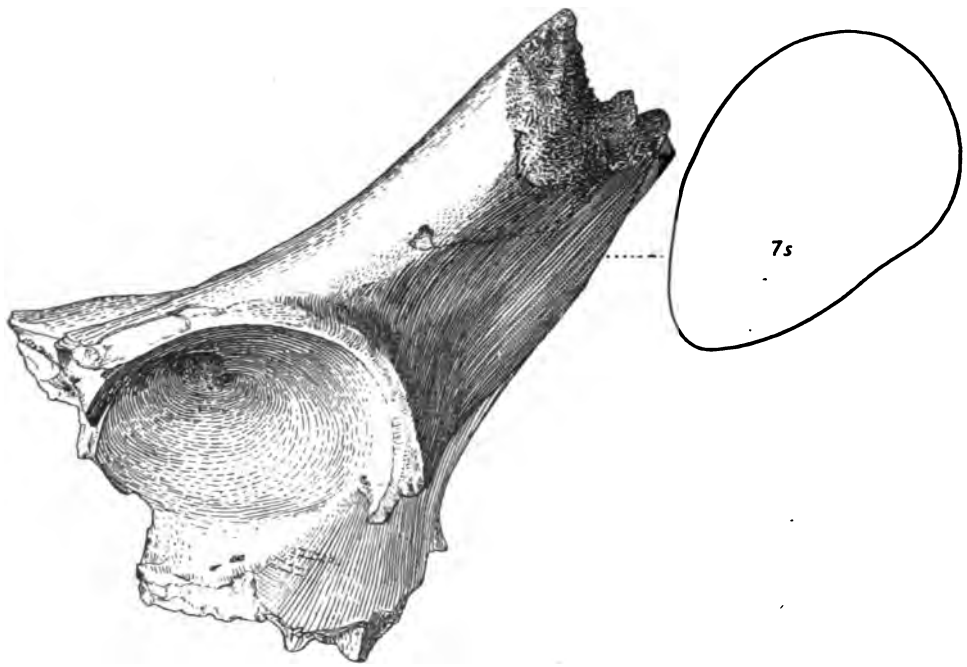

Fig. 7.—*Sphenophalos nevadanus.* Outer side of left horn core and orbital region; *7s*, cross-section of horn core. No. 11887, type sepcimen, natural size.

The type specimen (fig. 7) consists of the basal portion of the left horn with a portion of the frontal extending forward over the orbit, and backward to form a small portion of the brain case. A second specimen, no. 11888, includes the bases of both horns with portions of the orbits and brain case, and represents an individual a little smaller than the type.

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This form differs from the typical *Ilingoceros* in the flattened form of the horn core, which shows only the slightest tendency to twist in the specimens available. The cross-section of the horn cores is wedge-shaped, the anterior edge being narrower than the posterior. The antero-external angle of the core rises above the orbit in a line almost parallel with the long axis of the horn, while in the typical specimens of *Ilingoceros* the anterior ridge arising above the postero-superior region of the orbit swings backward sharply across the long axis of the horn and quickly twists around its base.

The posterior aspect of the base of the horn core is also quite different from that of the typical *Ilingoceros,* as a perfectly even surface reaches up from the brain case and extends over the posterior side of the horn core. In *Ilingoceros* this region is crossed by the sharply twisting spiral ridges (fig. 1).

SYSTEMATIC POSITION OF ILINGOCEROS AND SPHENOPHALOS.

The forms which have been included in the genus *Ilingoceros* as described above seem to belong near the strepsicerine or tragelaphine division of the antelope group. This sub-family is known at the present day only in the African region, unless, as some writers have held, the peculiar *Boselaphus* of India be grouped with the African forms. It was represented by several typical twisted-horned types in Europe and Asia in later Tertiary time. No member of this most specialized group has heretofore been known in the Western Hemisphere.

The type specimen of *Ilingoceros* resembles *Protragelaphus* from the Pliocene of Europe and Asia in some characters, but differs in the position and in the general character of the spiral ridges, in the more erect position of the horns, and in the greater width and flatness of the region between the bases of the horn cores.

The small specimen, no. 11893, tentatively referred to *Ilingoceros* as group C, most nearly approaches *Protragelaphus,* though it is by no means identical with it in form of horn core. A fragmentary specimen, no. 11886, which has been considered as probably representing a portion of a horn core of *I. alexandrae* farther removed from the base than the upper end of the type

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specimen, suggests the form of the basal region of a horn core from Maragha, Persia, which has been considered by Weithofer[4] as possibly a young individual of *Protragelaphus skouzesi*. It is not improbable that the Maragha form referred to may represent a type distinct from *Protragelaphus*.

The typical *Ilingoceros* differs from *Prostrepsiceros* in the position and form of the spiral ridges, apparently also in the sharper twist of the spiral, and in the wider space between the bases of the horns.

In *Palaeoreas* the anterior spiral ridge rises higher up on the base of the horn than in *Ilingoceros* and is much nearer the median line of the skull, so that the general aspect of the horn is quite different from all points of view.

The specimens included in the genus *Spenophalos* resemble *Ilingoceros* and the tragelaphine division of the antelopes in the absence of cavities at the base of the horn cores, as also in the density of the horn core as a whole. In the specimens available the horns are much flattened laterally, and have evidently not developed a series of spiral ridges like those of *Ilingoceros*, or the typical strepsicerine forms. The nature of the frontal region does not differ greatly from that of *Ilingoceros*.

Sphenophalos resembles the existing prong-horn antelopes somewhat in the general form of the horn core, and probably also in the character of the surface of the core. The horn cores of *Sphenophalos* differ from those of *Antilocapra* in their relatively greater thickness, and in their more oblique position with reference to the long axis of the skull. They also occupy a slightly more posterior position with reference to the orbit and are directed backward, instead of standing erect as in *Antilocapra*. The posterior side of the base of the horn core in *Sphenophalos* presents a broad, flat, gently-curving surface, entirely different from the narrow, prominent posterior edge of the base of the horn core in the prong-horn. There is also a noticeable difference in the slope of the roof of the skull behind the horns, this region dropping away from the plane of the forehead more sharply in *Sphenophalos* than in *Antilocapra*.

[4] Weithofer, K. A., Denksch. d. k. Acad. d. Wiss. Math. Naturwiss. Cl., Bd. 57, Taf. 5, Fig. 2.

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The resemblance to the prong-horns which is shown in the horn cores of *Sphenophalos* will mean very little if the horns of *Sphenophalos* be found to be of the long, slender type of the true antelopes. The only suggestion that they may have been relatively short is given in the slight tendency of the horns to flare a short distance above the base. It is hoped that later finds may furnish material which will make possible a determination of the entire outline of the horn core.

With the fragmentary material available it is probably not desirable to attempt the definite reference of *Sphenophalos* to any of the existing subdivisions of the antelopes, although it appears to be not far removed from the tragelaphine forms of the Thousand Creek fauna.

The collections from the Tertiary beds of the region of Virgin Valley and Thousand Creek have been as yet only partially examined, and in the present communication only the horn cores have been described, as they seem for the present to constitute the most satisfactory basis for comparison. No reference has been made to a number of specimens representing dentition and general skeletal structure, as the scattered and fragmentary nature of the material is such that only a most careful study will make a correlation of the parts possible. It is probable that a more exhaustive study of the collection will considerably increase our knowledge of these forms, as the dentition of the antelopes has been well described, and made available for comparison by Schlosser.[5]

RELATED FORMS IN AMERICA.

With the exception of the rupicaprine or chamois group as represented by the mountain goats, the true antelopes which are so wonderfully represented in the Old World have not until recently been known to have been present at any time in the fauna of the New World.

In an important paper on "A Pliocene Fauna from Western Nebraska" Dr. W. D. Matthew and Mr. Harold Cook have recently described[6] a most interesting fauna resembling that from

[5] Schlosser, M., Abh. Mat. Ph. Cl. k. Bay. Akad. d. Wis., Bd. 22, p. 161.

[6] Bull. Amer. Mus. Nat. Hist., vol. 26, pp. 361-414.

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Thousand Creek, Nevada, and containing remains of a form considered by them to represent the tragocerine or hippotragine division of the antelope group, which has hitherto been known only from Europe, Asia, and Africa. The horn is short and straight, with a round-oval cross-section. Its surface resembles that of the horns of the Bovidae, and differs from the prong-horn antelope in its comparatively coarse pitted structure.

There is in the University collections a fragmentary specimen from Thousand Creek representing a small portion of a horn core which corresponds very closely in form to about one-third of the horn core of the type specimen *Neotragocerus improvisus* as figured by Matthew and Cook. The cross-section of the horn core is approximately circular and there is no evidence of the presence of spiral ridges. The core narrows rather sharply toward one end, which presumably indicates that the horn was short. It appears to narrow too rapidly to represent simply the tip of a tragelaphine horn. As nearly as can be judged from this specimen there is good reason to think that it is either a form near *Neotragocerus,* or is an early representative of the *Aplocerus* or mountain goat type.

Associated with the antelopes from Thousand Creek there are a number of representatives of the *Merycodus* type, and with these there is one specimen which resembles *Merycodus,* and also suggests *Sphenophalos.* If the lowest beds of the Virgin Valley formation are found to contain these forms, it might be profitable to consider carefully the possibilities of American origin of some of the antelopes here described. It may also be profitable to consider the relationship of the existing American antelopes or antelocaprines to some of the forms represented in this fauna.

Issued December 16, 1909.

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UNIVERSITY OF CALIFORNIA PUBLICATIONS

BULLETIN OF THE DEPARTMENT OF

GEOLOGY

Vol. 5, No. 23, pp. 331-380, Pls. 27-39 ANDREW C. LAWSON, Editor

BENITOITE, ITS PARAGENESIS AND MODE OF OCCURRENCE.

BY

GEORGE DAVIS LOUDERBACK.

WITH CHEMICAL ANALYSES BY

WALTER C. BLASDALE.

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INTRODUCTION.

A brief announcement of the recently discovered mineral benitoite was made in a preliminary paper issued in July, 1907.[1] The purpose of the present paper is to give a general description of the nature of the occurrence and a more complete account of the major minerals than was possible at that time. The writer is indebted to Mr. R. W. Dallas, vice-president and manager, and Mr. Thomas Hayes, superintendent of the Dallas Mining Company for permission to visit the mine and for assistance in obtaining material for study; and to Shreve and Company of San Francisco and in particular Mr. G. Eacret, head of the diamond department, for gem and other material and assistance in many ways during the progress of the work.

Since the public announcement of the discovery of this beautiful gem mineral many efforts have been made to find new occurrences of it, but so far without success. The writer has, in connection with another problem, examined several hundred occurrences of analogous deposits, and several other geologists who have worked in the Coast Ranges of California have taken

[1] *Benitoite, a New California Gem Mineral,* by George Davis Louderback, with Chemical Analysis by Walter C. Blasdale. *Univ. Calif. Publ. Bull. Dept. Geol.,* V, No. 9 (July, 1907), pp. 149-153. Announcement was then made that new material had been received and a more complete report would follow. The main points of this latter report were presented before the Geological Society of America at its Albuquerque meeting in December, 1907. Various causes have contributed to the delay in publication of this material, in particular a severe illness which has kept the writer from the field of activity for the greater part of a year. In returning now to the completion of the manuscript for publication it is found that recently certain phases of the work have been duplicated by others. The results are presented here, however, as they were originally worked out by the writer and his co-worker and reference made to the other articles at the end of the paper.

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particular notice of minerals and veins occurring in similar geologic surroundings without seeing either of the more characteristic minerals of this particular deposit. And it is not because these minerals are difficult to see, for on the contrary they are striking in appearance. They do not occur as microscopic forms, but always in distinctly visible crystals commonly of fairly good size. It would appear reasonable to conclude that the minerals have not been simply overlooked, but that they are really very restricted in their occurrence and are due to a special and unusual set of conditions—a peculiar variation, as the writer believes, of a type of geologic activity of rather general occurrence along the Coast Ranges. The locality and general geological surroundings therefore assume considerable interest.

THE LOCALITY.

The only locality of benitoite known at present lies in San Benito County, California, near the Fresno County line, on a short tributary of the San Benito River which joins the latter near its source. It is on the west side of the Diablo Range and not far from its summit line, and about twenty-five miles in a straight line (probably thirty-five miles by road) north of Coalinga, where the mining company that owns and works the property has its headquarters and from which it ships its supplies.[2] Its geographical position is represented on the index map, plate 27. The mine is located on section 25, township 18 south, range 12 east, Mount Diablo base and meridian.

[2] It has been found very difficult to determine just who is the discoverer of this interesting deposit. Different individuals have laid claim to this title and a comparison of their various accounts shows that the ambition to be so called has led to misrepresentations of the facts. As the writer has already given names in his preliminary report and has found that the original accounts given him are not entirely correct, he feels that a further statement is due. Mr. J. M. Couch, a prospector of Coalinga, grubstaked by Mr. Dallas, had in December found some deposits that seemed to need further examination, and Mr. Dallas induced Mr. L. B. Hawkins of Los Angeles to accompany Couch into the mountains for that purpose. While out to examine some copper prospects they happened on the benitoite deposit and each claims to be responsible for the discovery. Having no idea of the nature of the material, they took some back to town for further enlightenment. At first the idea, expressed by some "expert" in Los Angeles, prevailed that the material was volcanic glass and of no value. Later some stones were cut in San Francisco, the lapidary believing that they were sapphires, and for some time the property was known as the Sapphire Mine.

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GENERAL GEOLOGICAL SURROUNDINGS.

The Diablo Range is primarily a range of folding and is essentially anticlinal in its structure. The rock formations of which it is composed rise up from the "Great Valley" on the east exposing in the characteristic way, and chiefly through the effects of erosion, older and older strata as we approach the summit region, the rocks dipping to the west and appearing in reverse order as we descend the western slope. Often the general rise from the Great Valley is marked by one or more gentle or subsidiary folds, or it is modified by faulting, and such variations are especially common on the west side where the main range is flanked by a more or less mountainous country as far as the coast.

However, the Diablo Range is not in its general nature a single great anticline with axis practically coincident with the range line. It consists of a series of anticlinal axes arranged en echelon, their strikes lying generally more west of north and south of east than the topographic summit line. In contrast to the subsidiary or minor flanking anticlinal folds, these may be called the primary anticlinal components of the range. The noses of these component folds run out into the valley, gradually flattening down until they disappear. These anticlines are so placed with respect to each other that the summit divide runs along one for a greater or less distance, and then dipping down to a pass rises again to the next axis, and so on. The outcropping strata pass along the flank of the anticline, swing about the end and turn back into the range, then curve about in the opposite direction along the synclinal axis and out along the flank of the next succeeding anticline.

By reference to the map (plate 27) the general nature of the structure in the vicinity of the benitoite locality can be recognized by its influence on the topography. From some distance to the north of the mineral occurrence an axis of a primary anticlinal component occupies the summit region, and passing a short distance to the east of the gem mine continues in a southeasterly direction and runs out some miles into the valley, where it pitches below the plain just northeast of Coal-

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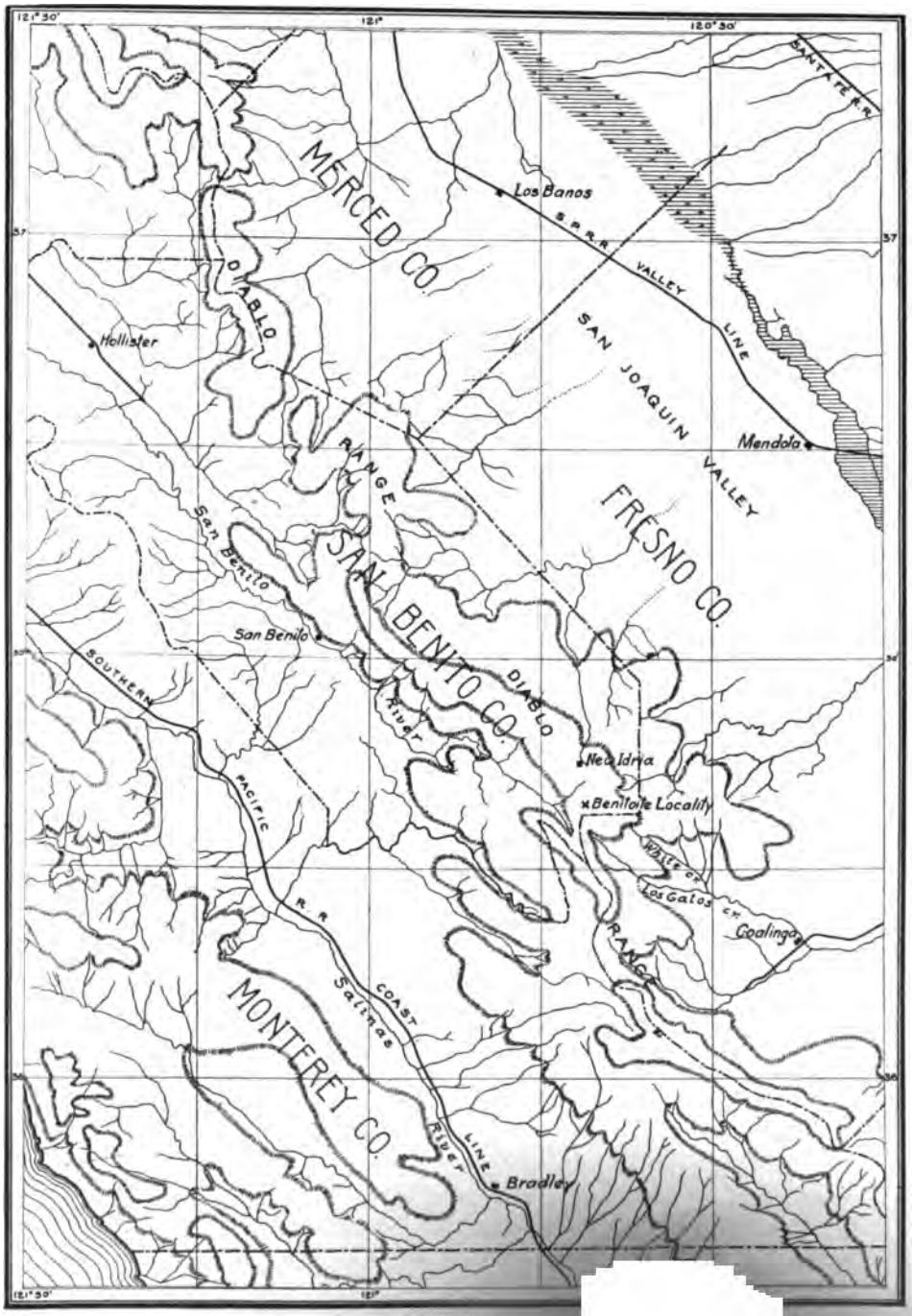

INDEX MAP.

South Central Coast Ra

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inga. This particular anticlinal lobe is of considerable interest in another way, for its lower portion near the valley has produced and is producing large quantities of petroleum, and it was along the nose of this anticline that the first important development of the Coalinga oil fields took place.

The next succeeding primary anticlinal component forms that part of the range to the west of Los Gatos Creek and Coalinga. The synclinal area between the two is well marked topographically by the depression in which flows Los Gatos Creek and its tributary, White Creek, the pass at the head, and the depression occupied by San Benito Creek on the western slope. These corresponding depressions (in part structural, but modified by erosion) and the saddle between them naturally determine the position of a road crossing the mountains from the interior valley towards the coast, and this is the road followed to reach the benitoite locality from Coalinga.

Ascending the mountains one sees a remarkable display of formations starting with the Recent of the valley, crossing in succession various divisions of the Quaternary, Pliocene, Miocene, Eocene, Upper and Lower Cretaceous and ending with the Franciscan which with its associated intrusives occupies the highest portions of the range. It is in these last named rocks that the minerals under discussion occur.

Owing to the general structure just described, the exposures of the Franciscan and their associated igneous rocks do not everywhere occupy the summit line of the main range, but extend out along the axes of the anticlinal components. Thus these rocks of the benitoite locality extend southward along the spur that runs into the valley northeast of Coalinga, while later rocks occupy the divide at the pass. The older rocks again appear at the surface along the range line farther south along the axis of the next anticlinal component.

All of the rock formations of this section down to and including the Knoxville (usually considered Lower Cretaceous), as is common in the Coast Ranges, are unaltered or but slightly altered sediments and show nothing in the nature of schist formation and very little in the way of veination—and this of superficial origin. The Franciscan series is in marked contrast.

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It consists of more or less altered sandstones (often more properly graywacke), shales (frequently slates), radiolarian cherts and local areas of various types of more or less recrystallized rocks, which are frequently coarsely crystalline schists. This series is also intruded by various types of basic igneous rocks and by dikes and large (bathylithic?) masses of serpentine. A particularly large mass of serpentine occupies the summit region of the anticline north of Coalinga; and it is in the midst of this that the benitoite mine is located. It is the same mass that has been referred to in the literature as passing just back of the New Idria quicksilver mines which are situated about five or six miles north of the benitoite locality. In the vicinity of the gem mine it is several miles wide and extends down the range some distance to the southeast.

Scattered through this serpentine area are included patches of the Franciscan, sometimes of considerable size and sometimes only a few yards or even feet across. These patches may consist of any of the types of rocks mentioned above or any combination of them with or without associated basic igneous materials. Patches of schist are quite common and of considerable variety, including glaucophane, actinolite, hornblende, garnet, mica, chlorite and other schists, and they often carry well-developed crystals either as part of the body of the schist or in the veins by which they are frequently traversed. Attempts have been made to discover some regularity of strikes, or dips or other structural relations, but without success. These patches appear in general to be detached masses included at the time of the intrusion of the serpentine, and to bear no particular relationship in their attitude to the roof or country from which they were separated.

It is in one of these masses inclosed in the serpentine that the mineral deposits under consideration are found.

OCCURRENCE.

Benitoite occurs in a zone of narrow veins of natrolite, which traverses an irregular lens-shaped inclusion in the serpentine.[3]

[3] The occurrence of the minerals is also discussed by Arnold: *Science*, n. s., Vol. XXVII (1908), pp. 312-314.

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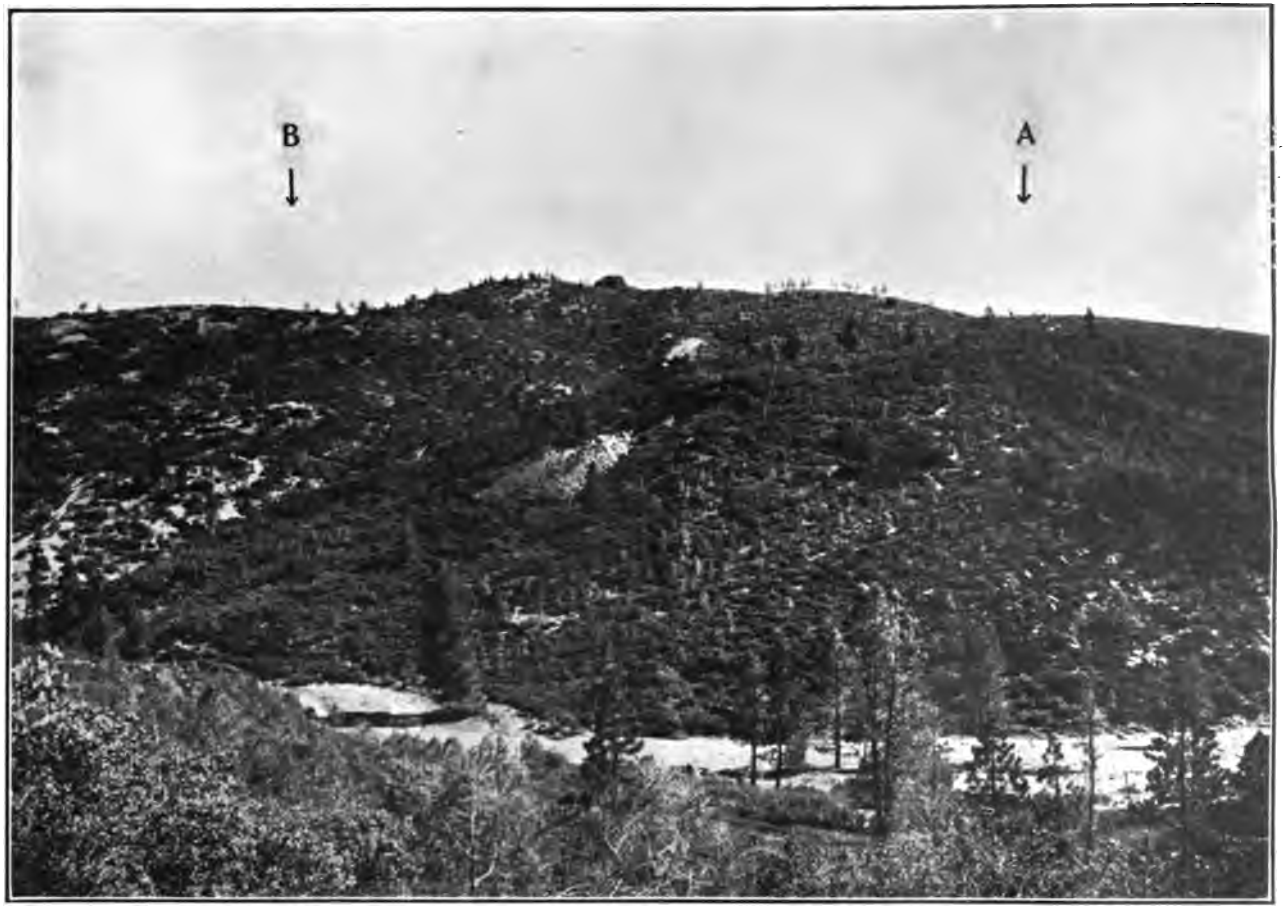

General view of benitoite locality and mine, August, 1908. B-A, limits of included rock mass in which the zone of mineralization occurs.

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The outcrop occurs on a hill which, as shown in plate 28, is separated from the neighboring ridge by erosional depressions on all sides. Practically all of the country in view in this photograph, which was taken looking a little east of north, is serpentine, including the basal portion of the mine hill. The rock mass directly associated with the veins lies along the top of the hill from a point directly below A to one directly below B, and is about 520 feet long, and perhaps 400 feet in its widest part.

The outcrop of the mineralized belt lies entirely on the side of the summit visible in the photograph and extends along a line determined in the photograph by the right end of the cut and top of the dump. It is a zone of veination which consists of a large number of irregular stringer-veins running along together in the general direction of elongation of the zone, and connected by many branches and anastomosing laterals. The rock in the vicinity of the veins is altered by recrystallization, metasomatosis, and impregnation, in some places porous from solution of certain constituents, in others tough and cemented by natrolite impregnation.

EFFECTS OF EARTH MOVEMENT AND PRESSURE.

Considerable movement has taken place both before and since the mineral deposition, and it is distinctly concentrated along the mineralized zone. The great majority of the planes of movement and crushing lie in or near the plane of strike of the zone of mineralization, but a few are transverse.

The effects of pressure may be tabulated:

Genetically related to deposit.	1. Local schistosity. 2. Cracks and spaces giving loci of veins and druses.
Subsequent to deposit.	3. Sheeting, crushing, and brecciation. 4. Faulting and displacement of veins.

In the first three of these groups the planes lie approximately in the zone of mineralization. A few of the later fault-planes are transverse and have displaced the veins and rendered the deposits more or less discontinuous.

The appearance of schistosity in the massive rocks seems to be limited to the immediate vicinity of the zone of veination

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and the planes of schistosity lie roughly parallel to the outcrop. This is especially noticeable at the east end of the zone where the rock is a fine-grained greenstone, and along the line of the zone shows incipient schistosity and is traversed by narrow veins of natrolite lying chiefly in the planes of foliation.

The cracks and spaces in which the veins have been deposited are not always completely filled, and drusy cracks and geodal cavities are quite common. As might be expected, many of the best crystals, and almost all of the better specimens, are obtained from such drusy spaces. Often the filling has proceeded so far that while a number of the crystals from opposite walls have united, the majority are still free. These may be split open. Plate 29 shows a slab three feet long and eighteen inches maximum width which has been so opened, exhibiting the corresponding drusy surfaces. Plate 30 and plate 33 show smaller surfaces more in detail.

Sheeting is very marked in the face of the open cut, as can be distinctly seen in plate 31. To the right of the rope it is very well developed with vertical planes. It occurs in other parts of the mine also. Crushing is evident here and in other places where sheeting is not developed.

It is interesting in this connection to note that eastward beyond the limits of the vein-bearing rock-lens, and in continuation of the direction of the zone of mineralization, the serpentine is badly brecciated.

Evidences of movement are very plentiful—both fault-planes and displacements. In the face of the open cut (plate 31) the rope lies on a very distinct plane of movement. To its right is crushed, sheeted, and altered greenstone; to the left the vein-stone and tough impregnated wall-rock is seen broken into separate blocks.

This crushing and faulting of the mineralized zones allows the ready seepage of water, and therefore favors decomposition. The rock outside the impregnation zone has suffered the most from this, and especially in the sheeted areas has suffered so from oxidation and other changes that it is often impossible to get a definite idea of its original nature. In the mineral druses, where permeable, the waters have deposited a layer of limonite

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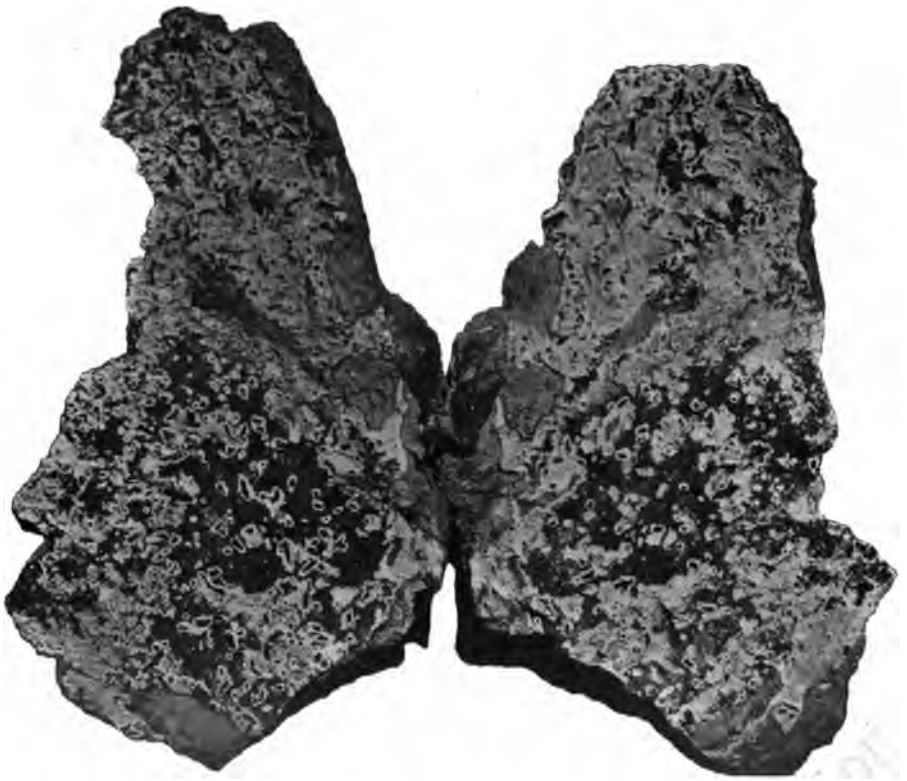

Portion of vein split open to show drusy interior. Benitoite and neptunite crystals, and white natrolite veinstone partially coated with a limonite film. About ⅙ natural size.

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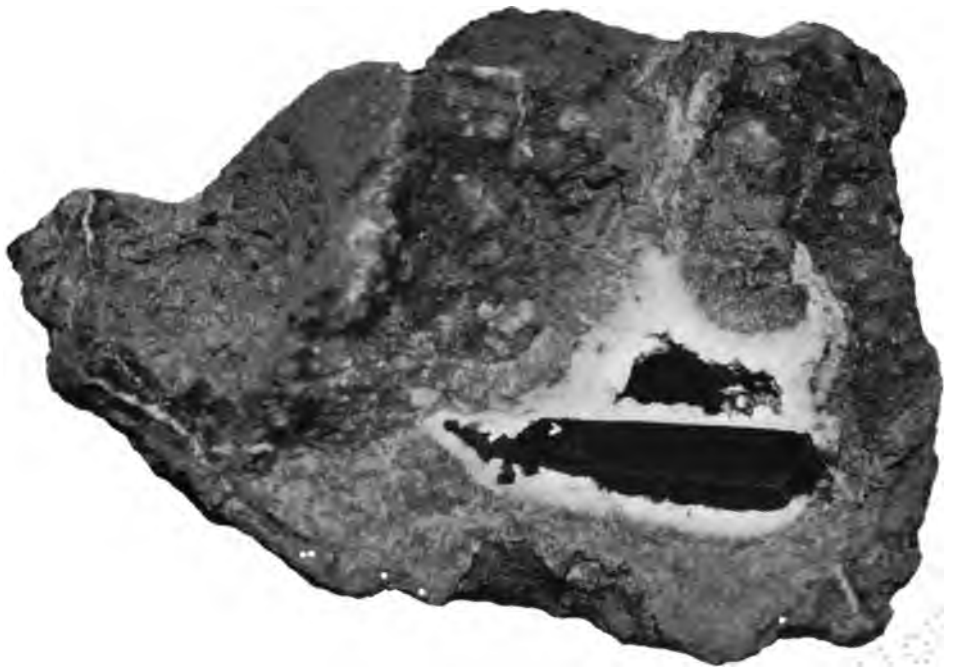

Neptunite prism in natrolite druse. The inner pure white natrolite is separated from the soda amphibole rock by a layer of greenish natrolite.

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over the natrolite, and disfigured its shining pure white surface. The general dark areas in plate 29 are due to limonite films. Fortunately, the benitoite and most of its associates are very resistant to weathering, and besides they are generally well enclosed in impregnated blocks that shed the water into their more porous neighbors. Plate 32 is a more general view of the face of the cut, and the distribution of vein-stone can be there better followed. The rope lies on the fault-plane, and to its right is the sheeted greenstone. Starting from the curve in the rope, to the left a number of harder blocks are to be seen lying almost on a level. These are all "ore". Above them is a greenish blue, porous, highly altered country, characterized by an extensive development of green to blue amphiboles. At the left edge of the photograph is a large mass extending to the floor of the cut. It is evidently a breccia, and is highly impregnated. It also is "ore", if in part low grade. This mass extended out originally into the cut, where it was separated from the vein-stone in the face as a result of a transverse fault. The zone here dips to the left. Its irregularity is evident. The highest visible point of the rim is thirty-seven feet above the floor of the cut.

We may consider briefly the practical bearings of these post-veination movements. They have increased the difficulty of mining by producing irregularity and discontinuity of the gem-bearing matrix, by leaving the rock in a weakened condition so that movement and caving are always imminent, and by affording ready access of surface water into the workings.

The workings are at present so shallow that there is not sufficient evidence on which to base an opinion as to whether these conditions will change or not with increasing depth.

SIZE AND ATTITUDE OF OUTCROP.

The outcrop of the mineralized zone is not very extensive. At its widest point it is about sixty-four feet. Its length is not over four hundred feet. Of this the easternmost part carries barren natrolite veinlets and the wall-rock shows a minimum of metasomatic alteration. Benitoite has been found at the surface along only about 230 feet of the zone, and at the extremes of this distance only in very small quantity.

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The general trend of the outcrop is north 64° west. In the cut the western part dips about 68° north, while in the face it dips 65° north. At the east end of the mineralized zone the greenstone with incipient schistosity and the barren veins of natrolite lying in these planes strike north 59° west and dip 75° north. In other words, the zone turns slightly to the south before dying out.

GENERAL RELATIONS OF MINERALS IN VEINS.

The most abundant mineral of the veins is natrolite, which occurs chiefly in granular aggregates. Indications of crystal form are largely limited to the drusy cavities, and even there the natrolite generally forms in peculiar groups, projecting in small roof-shaped ridges or coxcomb-like forms, and only very rarely developing the prismatic forms usually characteristic of natrolite. Some of the druses are filled with very small needles of green or blue-green amphibole, and lying in the midst of the cavity supported by these needles the natrolite often occurs as equant[4] polyhedral aggregates of from 1 to 3 millimeters in diameter, not at all suggestive of the mineral natrolite. Most conspicuous and beautiful in this white ground of the natrolite gangue are the scattered idiomorphic crystals of the blue equant or somewhat tabular benitoite and the brilliant black neptunite prisms, showing here and there a touch of deep red. These minerals are the characteristic and more abundant minerals of the benitoite-bearing veins.

In plate 30 it is apparent that surrounding the drusy cavity is a layer of white (natrolite) and that it is followed by a layer of darker color. This outer layer is of variable thickness—from a fraction of an inch up to several inches —and is usually present between the white vein material and the more definitely recognizable wall-rock. It has a bluish or greenish tint, and looked at closely is seen to show a granular structure with luster and cleavage much like the vein-stuff. It is indeed natrolite which is loaded with numerous microscopic

[4] Used in the sense of equidimensional or nearly so, in contrast to tabular or prismatic, as suggested by Cross, Iddings, Pirrson and Washington, *Journ. Geol.*, XIV (Dec., 1906), p. 698.

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Detailed view face of open cut, benitoite mine, August, 1908. Sheeted zone on right, discontinuous masses of veinstone on left.

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needles of greenish or bluish amphibole, etc., and recalling in its general nature the "Eisennatrolith" of Norway.

Following this is the more or less altered wall-rock, which along the central part of the deposit is made up largely of bluish or greenish amphibole in minute prisms or needles or irregular tangled mats. It often has a rather porous and irregular texture, as the result of considerable leaching of the original rock substance.

THE MINERALS OF THE DEPOSIT.

BENITOITE.

Crystallography.

Benitoite crystallizes in the trigonal division of the hexagonal system and, as will be more fully shown below, it belongs to the twenty-second or ditrigonal-bipyramidal group of Groth, the trigonotype group of Dana—the first actual example of this type of symmetry. This is the highest symmetry group of the trigonal division—too high to exhibit rhombohedra which are so characteristic of this division that it is often called the rhombohedral division or system.

The axial ratio $c:a$ is 0.7344, determined as the average of 27 direct measurements of the angle between p $(10\bar{1}1)$ and c (0001) with the two-circle goniometer.

The detailed data obtained from 7 crystals are as follows:

40° 14′ —2 good, 1 fair.
16½′—1 good, 1 poor.
18′ —4 excellent, 3 good, 7 fair, 2 poor.
19′ —1 excellent, 1 poor.
21′ —1 good, 1 fair.
22′ —2 fair.

Giving weights of 4, 3, 2, and 1 for excellent, good, fair, and poor reflections, respectively, the average is 40°17′94; a simple average, all readings being given same weight, gives 40° 18′04. The closeness to the value for apatite (Dana, 0.7346[5]) is striking, but the symmetry is different and the relationship otherwise not apparent.

[5] Baumhauer in *Zeit. für Kryst.*, XVIII (1891), p. 40, has collected the various values for the axial ratio of apatite and gives values from 0.7294 to 0.7353.

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The elements according to the system of Goldschmidt, as $a : c = 1 : 0.7344$ (G_1), are as follows:
(10)

$c = 0.7344$	$\lg c = 9.86593$	$\lg a_o = 0.37263$	$\lg p_o = 9.68984$	$a_o = 2.3585$	$p_o = 0.4896$	G_2

or by selection of the other set of axes,

$c = 1.2720$	$\lg c = 0.10449$	$\lg a_o = 0.13407$	$\lg p_o = 9.92839$	$a_o = 1.3617$	$p_o = 0.8480$	G_1

TABLE OF ANGLES. G_1.

No.	Let.	G_1	G_2	Bravais	ϕ	ρ	ξ_0	η_0	ξ	η	$\frac{x}{y}$ Prisms	y	$d = tg\rho$
1	c	0	0	0001	——	0°00′	0°00′	0°00′	0°00′	0°00′	0	0	0
2	a	∞	$\infty 0$	$11\bar{2}0$	30°00′	90 00	90 00	90 00	30 00	60 00	0.5773	∞	∞
3	m	$+\infty 0$	$+\infty$	$10\bar{1}0$	0 00	90 00	0 00	90 00	0 00	90 00	0	——	∞
4	μ	$-\infty 0$	$-\infty$	$01\bar{1}0$	60 00	90 00	90 00	90 00	60 00	30 00	1.7321	∞	∞
5	p	$+10$	$+1$	$10\bar{1}1$	0 00	40 18	0 00	40 18	0 00	40 18	0	0.8480	0.8480
6	π	-10	-1	$01\bar{1}1$	60 00	40 18	36 19	22 59	34 04	18 52	0.7349	0.4240	0.8480
7	r	$+\frac{1}{2}0$	$+\frac{1}{2}$	$10\bar{1}2$	0 00	22 58	0 00	22 58	0 00	22 58	0	0.4240	0.4240
8	d	2	60	$22\bar{4}1$	30 00	71 12	55 45	68 32	28 15	55 04	1.4687	2.5440	2.9375

A number of crystals show a more complicated form that lies vicinal to π and in the angle where π, m and p meet. These faces may occur complete for the symmetry as far as one face π and its corresponding face vertically below are concerned—that is, one in each of the corresponding p, π, m corners; but they have not yet been found corresponding to the complete symmetry of a whole crystal. They are uniformly dull, and give no opportunity for accurate measurement. Many attempts at measurement were made with unsatisfactory results, and the following approximation may be given: $x = -1\frac{1}{10}$ ($\bar{1}0\ 1\ 9\ 10$). At least one other was observed, and recognized as different by the different triangular trace that it produces, but it is so near π in its attitude and so dull that no approximation is attempted. x seems to be the more common of the vicinal forms and was observed on a number of crystals. It is of interest as the best-defined representative of a general form yet observed.

The positive set of planes give much better reflections than the negative set. μ ($\bar{1}010$) gives generally unsatisfactory reflections. The unit pyramid faces $\pm$ should show the simple relation that one appears at each $(\phi + n\,60)°$ with the same

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ρ=40° 18′; likewise a prism face at each $(\phi + n\,60)°$ with ρ = 90°. To illustrate the nature of the measurements obtained, results are here given for two crystals. In general it has been found that all of the individual faces of a form are not measurable on the same crystal.

Crystal No. 3

	Measured.		Reflection.	Calculated.	
	ϕ	ρ		ϕ	ρ
p^1	0° 00′	40° 18′	excel.	0° 00′	40° 18′
π^2	59° 59′	40° 14′	poor	60° 00′	40° 18′
p^3	119° 56′	40° 18′	good	120° 00′	40° 18′
π^4	broken				
p^5	240° 00′	40° 18′	excel.	240° 00′	40° 18′
π^6	299° 54′	40° 18′	fair	300° 00′	40° 18′
m^1	0° 00′	90° 00′	good	0° 00′	90° 00′
m^5	240° 00′	89° 58′	fair	240° 00′	90° 00′

Crystal No. 1

	Measured.		Reflection.
	ϕ	ρ	
p^1	0° 00′	40° 19′	excel.
π^2	60° 05′	40° 19′	poor
p^3	120° 04′	40° 22′	fair
π^4	180° 01′	40° 22′	good
p^5	239° 58′	40° 21′	good
π^6	300° 01′	40° 21′	fair
m^1	0° 00′	90° 00′	fair
μ^2	60° 04′	90° 00′	fair
m^3	120° 05′	90° 00′	fair
m^5	240° 01′	90° 00′	fair

		Measured.		Calculated.	
		ϕ	ρ	ϕ	ρ
r	$(10\bar{1}2)$	0° 02′	23° 00′	0° 00′	22° 58′
a	$(11\bar{2}1)$	89° 59′	30° 03′	90° 00′	30° 00′
		90° 00′	30° 04′		
d	$(22\bar{4}1)$	71° 07′	30° 03′	71° 12′	30° 00′
		71° 12′	30° 00′		

For a and d the two sets of readings are averages from two crystals.

For x the average on one crystal was ϕ=55° 22′ ρ=41° 48′; on another ϕ=54° 49′ ρ=41° 39′. The calculated angles for $-1\frac{1}{10}$ are ϕ=55° 07′ ρ=41° 48′.

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Habit.—The most common habits are distinctly trigonal and pyramidal. Although prism faces are almost universally present they are always comparatively small, and no approach to a prismatic habit has yet been observed. The largest crystal yet seen is about two and a half inches across, but is of unusual size. The majority are less than one inch across. The negative pyramid generally shows the largest faces, p commonly not reaching to c, and thus giving a triangular outline to the basal plane. The prisms appear as narrow bands. The basal plane may more rarely be absent, and p is then quite small. This gives the two habits shown in figures 1 and 2, plate 37. The positive pyramids reach the basal plane in about 20 per cent. of the crystals and then a hexagonal outline is produced, the edges generally being distinctly in two alternate groups (pl. 37, fig. 3). Only one crystal was seen wherein was produced a pseudo-hexagonal symmetry. A peculiar habit that has been found in a few crystals is produced by a predominant basal plane, the crystal being very thin, and, if growing from one side, has the appearance of an orthorhombic table.

Only one crystal was found not showing prism faces. The positive prism m may be narrower than the negative prism as in plate 38, figure 1, and in about 3 per cent. of the crystals examined it was absent, as in plate 38, figure 4. On the other hand, it may be considerably broader than the latter, even when its corresponding pyramid p is smaller than the negative pyramid π, as in figure 2.

The form r $(10\bar{1}2)$, has been found on considerably less than half of the crystals in which p does not reach the basal plane, and then always as a narrow truncation of the π edges. This is shown in figure 4, plate 37, together with x $(\bar{1}0\,1\,9\,10)$ which is here represented as complete for the crystal, although actually it is not found in all the sectants, and occurs only on a few crystals. In a certain number of crystals the place of r is then taken by a strip of horizontal striations or narrow planes due to oscillatory growth. The striations are shown in plate 38, figure 3, and in figure 4 is represented a set of coarser oscillations showing the origin of the striations as alternations of c and p.

The prism of the second order a $(11\bar{2}1)$ was observed in

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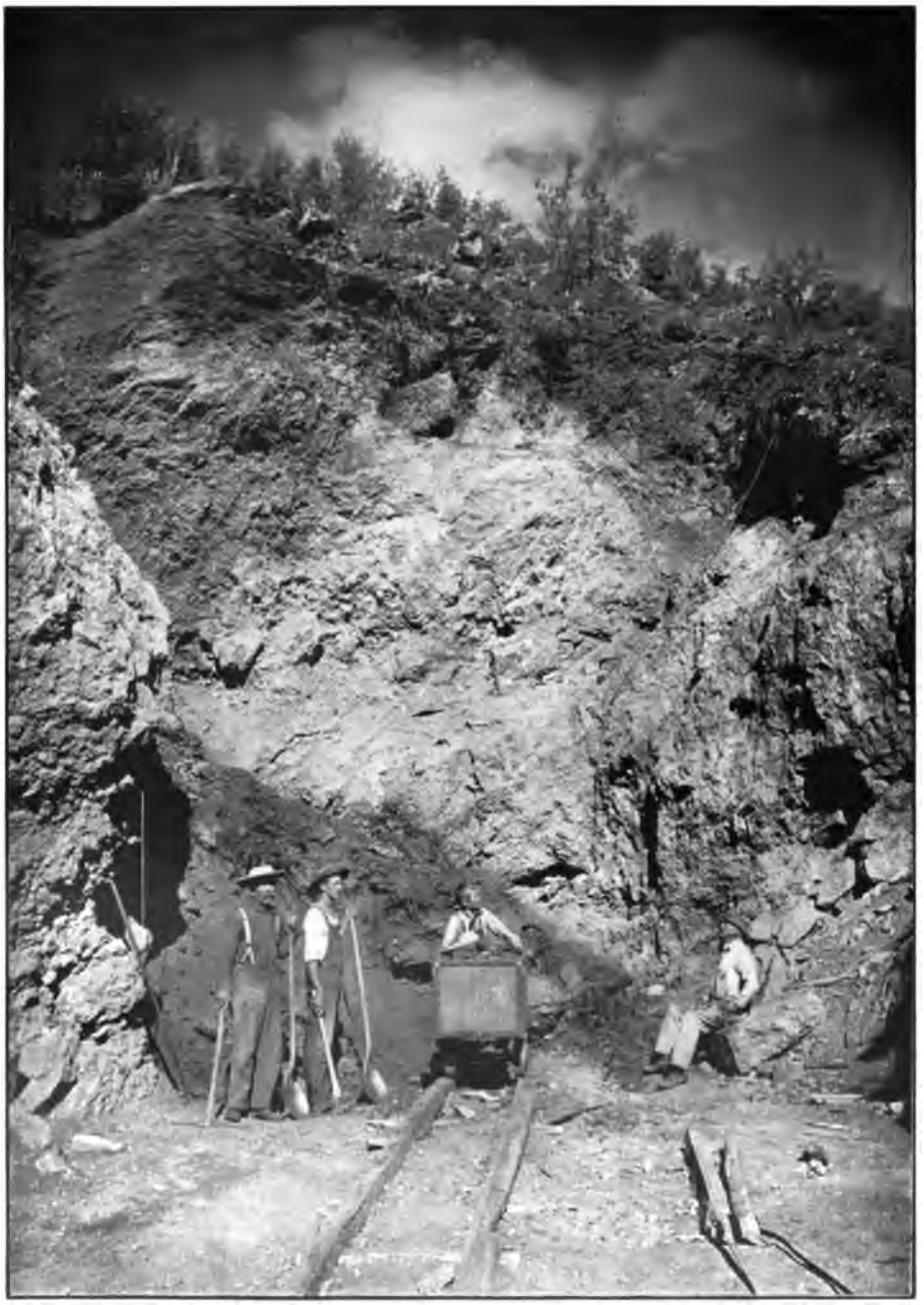

General view of end of open cut, benitoite mine, August, 1908.

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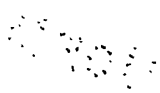

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about fifteen crystals in a lot of about 500 examined. It is always small and may occur without other planes of the second order, as in plate 38, figure 4, but it is commonly associated with *d* $(22\bar{4}1)$ as in figure 3 of this plate. This form, *a*, may be dull, and if bright is not so lustrous as either *m* or μ. The second order pyramid, *d* $(22\bar{4}1)$ was found on eleven crystals in the same lot. It is always small and with luster inferior to that of *a*. It generally accompanies *a*, but on two crystals showing an oscillatory growth between *c* and *p*, it occurs without *a*.

The basal plane is generally a very brilliant face, as also the pyramid *p*. The negative pyramid is frequently dull, and even when at its best is never as smooth and brilliant as the positive. Its surface is almost always uneven and often irregularly curved. This results sometimes in the production of a wedge-like form for the prism face, the edges $\pi \wedge \mu$ and $\bar{\pi} \wedge \mu$ converging towards the right or left. The prisms are generally quite bright, and if any difference appears, *m* shows a better surface than μ. Vertical striations of oscillatory growth are common on μ.

Symmetry.—The habit of benitoite is very characteristic of its trigonal symmetry, and of the presence of a plane of symmetry parallel to the base. The planes at each end of the vertical axis are always similarly developed, and the identity of the planes in the upper half with those vertically below are clearly shown, both by geometrical development and physical character. There may still be a doubt, however, as to whether the symmetry is that of the trigonal-bipyramidal or the ditrigonal-bipyramidal group. The simple forms that characterize the benitoite crystals are common to both groups. The planes of the second order occurring in like development at the end of each lateral axis, and vicinal form *x*, which is occasionally found, would indicate the group of highest symmetry.

Etch Figures.—Etching was also resorted to in the investigation of the symmetry. Good figures may be obtained on the base and the positive unit forms by treatment with hydrofluoric acid, and also with fused caustic potash, the results being similar in both cases. The figures with the acid are somewhat sharper and easier to handle and will be especially described.

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These etch figures are illustrated by figure 5, plate 37, wherein the basal plane remaining fixed, the pyramidal planes of the upper half of the crystal and the prisms are supposed turned on their upper horizontal edges until brought into the plane of the drawing. This gives the actually observed forms of the figures on each face, and exhibits clearly the symmetry. The broken lines are the traces of the three lateral planes of symmetry.

The basal plane remains brilliant and gives very distinct figures. These most commonly show the outline of equilateral triangles in position reversed with respect to the similar triangular outline of the basal plane, and with its sides parallel to the edges $c \wedge \pi$. On one crystal treated with very dilute acid hexagonal figures were obtained, but the face was also dotted by numerous small reversed equilateral triangles representing depressions of regular trigonal pyramidal form.

The negative unit pyramid π is the most readily attacked form on the crystal, and very soon becomes dull without showing any distinct figures. Under very favorable circumstances, peculiar figures are obtained, the upper boundaries of which are very indefinite, but which are distinctly symmetrical with respect to the projection of the c axis.

The negative unit prism (μ) shows generally rod-like or ellipsoidal depressions with sides or elongation parallel to the c axis. Where exceptionally developed figures of hexagonal outline are produced, two opposite sides are parallel to the c axis and the whole figure is symmetrical with respect to a horizontal and to a vertical line.

The positive unit pyramid p remains quite bright and gives good figures, usually quadrilateral and symmetrical to a diagonal parallel to the projection of the c axis on p. In some cases this quadilateral is truncated by a line parallel to the edge $p \wedge m$ at its upper angle, sometimes at its lower angle also. In a specimen treated with hot acid, depressions were obtained corresponding to a truncated hexagonal pyramid (not regular) as shown in fig. 5, plate 37.

The positive unit prism (m) is with difficulty attacked and generally shows only small pits with sides parallel to the

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c axis; occasionally minute lozenge-shaped figures may be seen in certain light, symmetrical with respect to the edges $\mu \wedge m$ and $c \wedge m$.

The figures on the basal plane show conclusively the trigonal character, and those on the prisms the presence of the horizontal plane of symmetry. It is also evident that three planes of symmetry pass through the vertical axis and bisect the pyramidal and prismatic faces, fixing the symmetry as that of the ditrigonal-bipyramidal group, and making benitoite the type of the highest grade of trigonal symmetry.

Natural Etching.—A large number of the crystals of benitoite show natural etching. The negative pyramids commonly show various degrees of dulling. This sometimes produces very striking results, especially when the crystal shows a large development of these planes with the other planes quite small, when the bulk of the surface may be very dull and even covered by a film of decomposition, in the midst of which the small faces may appear clear and brilliant. Triangular figures on the basal plane occasionally occur, sometimes as depressions when the triangle is in reversed position with respect to the triangle of $\pi \wedge c$, sometimes elevations when they are placed in the same attitude as triangle of $\pi \wedge c$. Occasionally hexagonal figures occur outlined by grooves parallel to the basal edges.

Physical Properties.

Hardness $6\frac{1}{4}$-$6\frac{1}{2}$; distinctly above orthoclase and labradorite, and below chrysolite and quartz. Density 3.64-3.67. The highest value obtained was on a flawless gem stone of moderately deep color weighing 1.53243 grams, and giving a value of 3.667. The clearest obtainable colorless fragment gave 3.65. A number of intermediate values were obtained on clear blue material and as low as 3.64. Material with flaws, cloudy white specimens, etc., in general give lower values.

Fracture, conchoidal to sub-conchoidal; cleavage very imperfect, pyramidal.

Refractive index by prism method referred to D line: $\omega = 1.757$; ϵ about 1.804. Double refraction strong, and positive.

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Basal sections show a perfect uniaxial cross which gives a distinct positive reaction with the mica plate.

Color, most commonly pale to deep blue, generally with a slightly violet tint; transparent. Colorless crystals occur, but are more rare. The variation in color frequently occurs on the same crystal, and the writer has many in which part of the crystal is blue and part colorless. The transition is sometimes gradual and irregular; sometimes it is sharp, the zones being separated by crystallographic planes. The writer has a slab cut parallel to the vertical axis to exhibit the pleochroism in which the line separating the blue from the colorless portion is parallel to that crystallographic axis. On another crystal a colorless layer 2 mm. thick lies at the top, and is separated from the bulk of the crystal which is blue by a plane parallel to its base. The physical properties of the colorless material are, except for those dependent on color, the same as those of the most highly colored ones.

An effort has been made to determine the source of the blue color of most of the material, but the results have so far been negative. Some of the colorless material was carefully separated and submitted to Professor Blasdale for chemical analysis, but it shows but slight variation (if any) from that of the blue, as may be seen by referring to the analyses given farther on. He also made a careful qualitative examination of a two-gram portion, but failed to detect any appreciable amounts of any element that might be reasonably supposed to influence the color of the minerals. That practically all of the titanium is in the highest state of oxidation was also shown by dissolving the material in hydrofluoric acid in an atmosphere of carbon dioxide. A colorless solution was obtained which failed to reduce potassium permanganate. In the preliminary report the writer suggested that the color might be due to a small amount of titanium in the reduced condition in solid solution in the benitoite molecule. A comparison of the analyses of colorless and blue samples shows that the TiO_2 of the former is a half per cent. or more less than in the latter, and if this can be accepted as an essential difference it at least is in consonance with that view. The violet-tinted blue of the extraordinary ray

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is also very suggestive of the color given by the sesquioxide of titanium. The reduction test stands opposed to this idea unless the quantity in the material used for the test was very small—or, in other words, unless very small quantities can give distinct colors.

The color is apparently quite stable. No evidence of fading has been noticed in the cut stones and fragments heated to a bright red, just short of fusion, for five or six minutes showed no change whatever after they were again cooled.

Pleochroism is very intense in the deep colored varieties and is probably the most important test applicable to cut stones. In the lighter parts the extraordinary ray is a very slightly greenish blue, inclining to indigo as it becomes darker, and is very similar to one of the axial colors shown by some cordierites. In the deeper colored crystals and the thicker layers it is an intense purplish blue. The ordinary ray is white. The color of the mineral in ordinary light is therefore merely the color of the extraordinary ray diluted with the white of the ordinary ray. The extraordinary ray shows strong absorption of sodium light, and renders a determination of the refractive index for that light difficult.

An attempt has been made to represent the pleochroism in plate 33, figures 2 to 4, as shown in a large cut stone. Figure 2 shows the natural color, and figures 4 and 3 the colors of the ordinary and extraordinary rays. The stone used is of only moderate depth of color. Dark colored specimens, if fairly thick, give such very strong absorption along the extraordinary ray that the depth of color is hardly reproducible.

It fuses quietly to a transparent glass at about 3.

Chemical Characters.

In hydrochloric acid it is practically insoluble, and this permits us to dissolve crystals out of their natrolite matrix without injury to the crystal faces. The natrolite dissolves, leaving the benitoite in a matrix of hydrous silicic acid which is easily removed. Sulphuric acid has also been used for this purpose at the mine. The mineral is attacked by hydrofluoric acid, and dissolves readily in fused sodium carbonate. Blasdale also finds it but slowly attacked by molten potassium pyrosulphate.

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The chemical analysis was kindly undertaken by Professor Blasdale. A and B were made on the blue material and C on the white.

	A.	B.	Av.	Mol. Ratios.	C.
SiO_2	43.56	43.79	43.68	.723	43.61
TiO_2	20.18	20.00	20.09	.250	19.50
BaO	36.34	36.31	36.33	.237	37.01
	100.08	100.10			100.12

From these is derived the formula $BaTiSi_3O_9$ which yields the following calculated values.

SiO_2	43.71
TiO_2	19.32
BaO	36.97

In an attempt to account for the color of the mineral Blasdale made various qualitative tests, and reports: "A more careful examination of a two-gram portion of the blue mineral failed to show the presence of appreciable amounts of iron, cobalt, manganese, copper or chromium. Very minute quantities of sodium and aluminum were obtained, but the amounts were so small as to render it probable that they were derived from the action of the reagents on the glass vessels employed rather than from the mineral itself. Conclusive evidence of the presence of the rarer earths, especially zirconium, tantalum and columbium, could not be obtained. Careful examination of some of the mineral in a delicate electroscope gave no indications of radioactivity." "It was also shown that all the titanium was present in the higher degree of oxidation. On dissolving the mineral in hydrofluoric acid in an atmosphere of carbon dioxide a colorless solution was obtained which failed to reduce potassium permanganate."

Benitoite is considered by both of us a very acid titanosilicate. Blasdale notes that the formation of salts of an extremely acidic character is not unusual when the acid concerned possesses very weakly acidic properties and the base very strongly basic ones, also that silicon dioxide possesses a remarkable tendency for the formation of complex poly-acids and that it is not improbable that the very closely related titanium dioxide might partially replace it atom for atom in such a compound as the mineral under consideration. He suggests that the

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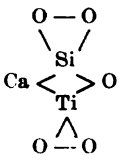
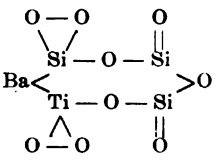
relationship of benitoite to titanite may be represented by the following formulae:

TITANITE



BENITOITE



Professor Kraus has recently stated objections to this view,[6] which was expressed in our preliminary paper. He considers the chemical composition of beryl and benitoite sufficiently similar to consider the compounds isomorphous, and interprets the composition of the latter as a metasilicate of barium and titanium of the formula $Ba_2Ti_2(SiO_3)_6$. The facts that it is associated paragenetically with the basic metasilicate natrolite and that the deposit is formed in basic rocks are also considered of weight in deciding the metasilicate character in contrast to that of an acid titano-silicate.

A general survey of the compounds of TiO_2 shows that it normally possesses the properties of a weak acid, and its common formation of titanates and titano-silicates is well known. That it may act as a base in combination with a strong acid is probable, but as far as known to the writer, no evidence that it may hold this relation to silicic acid has been found. It readily forms compounds in which it acts as an acid with only moderately basic oxides. In the present case, the temperature conditions for the production of the deposit being considered limited by the conditions for the formation of natrolite, SiO_2 may be looked upon as acting as a weak acid, while barium is a strong base. Without specific evidence to the contrary, then, it would be expected that the TiO_2 would act as an acid forming a titano-silicate. The intimate association of neptunite with the benitoite would suggest that the TiO_2 played the same rôle in each. In the latter the very strong bases soda and potash are present, and its character as an acid titano-silicate is gen-

[6] *Science*, n. s., XXVII (1908), pp. 710-711. Blasdale has discussed this point in Science, n. s., XXVIII (1908), pp. 233-234; on p. 234, line 19, the word "base" unfortunately appears where "acid" was intended.

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erally admitted; in fact, a few years ago it was characterized by Groth as "das Kieselsäurereichste aller Silikate," being considered a salt of pentasilicic acid, one of the five silicon atoms being replaced by titanium.

The association with contemporaneous natrolite can hardly be taken as indicating the basic character of the generating solutions—in fact, quite a different interpretation may be given. For many years Tschermak[7] has held that natrolite is an acid ortho-silicate of the formula $Na_2Al_2Si_2O_8.H_4SiO_4$. Doelter adopted this view and presented some suggestive evidence of it derived from its decomposition and synthesis, and secondary origin from nepheline.[8] Recently this matter has again been taken up experimentally by Tschermak[9] and Baschieri[10], and, as I believe, it has been very satisfactorily proven by the dehydration curve of the separated acid that natrolite is a salt of orthosilicic acid, the formula then indicating an excess of silicic acid in the solution. In regard to the basic characters of the country-rock as affecting the nature of the minerals in the veins, it may be noted that the polysilicate albite commonly occurs in veins in the glaucophane and other basic schists of the Coast ranges and in the schists themselves, associated paragenetically with glaucophane, actinolite and other metasilicates. Contrary to the inference drawn by Kraus, the effects of basic rocks on solutions carrying TiO_2, if the minerals of these rocks become involved in the action, should be to develop the acid characters of the TiO_2. As a matter of observation, titanite is a very common mineral in the glaucophane and associated basic schists. In some of the highly siliceous veins occurring in these rocks the main mass being quartz, the TiO_2 is found in the form of rutile, the basic elements not being present in sufficient quantity to permit its entering into combination. It does not, however, in such circumstances form a compound exhibiting a basic character toward silicic acid and, as Blasdale

[7] See for example his *Lehrbuch der Mineralogie* (1st edition), Wien, 1884, and repeated in his later editions.

[8] *Neues Jahrbuch für Mineral.*, etc., 1890, I, p. 134.

[9] *Sitzungsber. Akad. Wissensch. Wien.*, Math. Naturwiss. Klasse, Band 114, Abt. I (1905), pp. 455-466.

[10] *Rivista di Min., e Crist. ital.*, 36 (1908), pp. 37-48.

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has pointed out, the entire lack of such a compound, considering the frequent association of the oxides in the same formation, is striking.

Aside from these general considerations bearing on its chemical character, the symmetry and physical constants of benitoite do not appear to the writer to indicate any close relation to beryl.

Benitoite as a Gem.

Benitoite forms a beautiful gem stone, but only a small proportion of the crystals are suitable for cutting. It is generally cut as a brilliant to bring out both its color and the brilliancy and fire due to its high refractive power. The deep violet-tinted blue of the finer stones is very attractive and by many it is considered more beautiful than that of the sapphire, which it distinctly surpasses in fire and brilliancy. The color varies from colorless to very deep blue, the two extremes being the least common. The finest stones are those with a moderately deep color. Considerable judgment has to be used in getting the proper attitude and proportions to bring out the full color-value while preserving the brilliancy. Both color and brilliancy vary materially in different directions and the color is often distributed unevenly or zonally. Quite a number of stones which have been cut by various lapidaries do scant justice to the possibilities of the gem. A common result is the production of a sort of dull leaden, or in the darker varieties blackish appearance.

The large stones have a general run from a carat and a half to about two carats, only a few exceeding the latter value. The largest flawless gem yet obtained weighed a little over seven and a half carats when first cut, though it has since been repolished and brought down to a little below this value. It has a moderately deep blue color and is about 14.5 mm. long, 10.5 mm. wide at the girdle, and 8 mm. deep. It is the property of Mr. G. Eacret of San Francisco. This stone is remarkable in that it is about three times as heavy as the next largest flawless stone so far obtained, and also that it was found in the early days of the mine almost at the surface. It is shown actual size in plate 33, figures 1-4.

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Lately some very good results have been obtained by the use of the emerald cut which gives good color-value with but slight loss of brilliancy. A number of the stones have also been cut *en cabochon.* This allows the use of the less perfect material and also of that which varies considerably in color in the same piece, containing perhaps with the deep blue certain areas without color. The results have been quite satisfactory.

Name. The name of the mineral was taken from San Benito, the name of the county in which the mine lies, of the river, at the headwaters of which the deposit occurs, and of a nearby peak of the range.[11]

NEPTUNITE.

Crystallography.

Neptunite is an abundant and characteristic mineral of the deposit. Prior to its discovery in California it had been reported only from Greenland.[12] In the original benitoite material a small section of a prism without terminal faces was suspected to be a new mineral and the name carlosite suggested for it. Soon after the mine was visited satisfactory material was obtained and its identity with neptunite recognized.

The forms observed at the San Benito locality are $c(001)$, $b(010)$, $a(100)$, $m(110)$, $s(111)$, $o(\bar{1}11)$, $i(\bar{1}12)$, $g(\bar{2}11)$, $r(\bar{2}21)$, $p(\bar{3}11)$.

	Measured.				Calculated.			
	ϕ		ρ		ϕ		ρ	
$c(001)$	90°	00′	25°	38′	90°	00′	25°	38′
$a(100)$	90	00*	90	00*	90	00	90	00
$m(110)$	40	06	90	00*	40	07	90	00
$s(111)$	55	14	54	36	55	10	54	43
$o(\bar{1}11)$	$\bar{1}4$	06	39	53	$\bar{1}3$	57	39	45
$i(\bar{1}12)$	$\bar{1}9$	08	23	04	$\bar{1}9$	05	23	08
$r(\bar{2}21)$	$\bar{2}8$	27	61	25	$\bar{2}8$	37	61	28
$p(\bar{3}11)$	$\bar{6}2$	25	60	20	$\bar{6}2$	30	60	22

* Crystals set with prism zone at $\rho = 90° 00'$ and angles ϕ referred to a as 90° 00′

[11] The correct and usual pronunciation of place names of Spanish origin in California approximates the original Spanish pronunciation. In Benito the accent is on the penultimate syllable and the i has the sound of i in machine. In conformity with this, the name of the mineral is properly to be pronounced be-nĭ′-to-ite. Benito is a Spanish form of benedictus, blessed.

[12] Flink, *Zeit. für Kryst.*, 23 (1894), pp. 344-367; Nordenskiöld, *Geol. Fören. Förh.*, 16 (1894), p. 336; Wallenström, *ibid.*, 27 (1905), p. 149; Böggild, *Meddelelser om Grönland*, 33 (1907), pp. 95-120.

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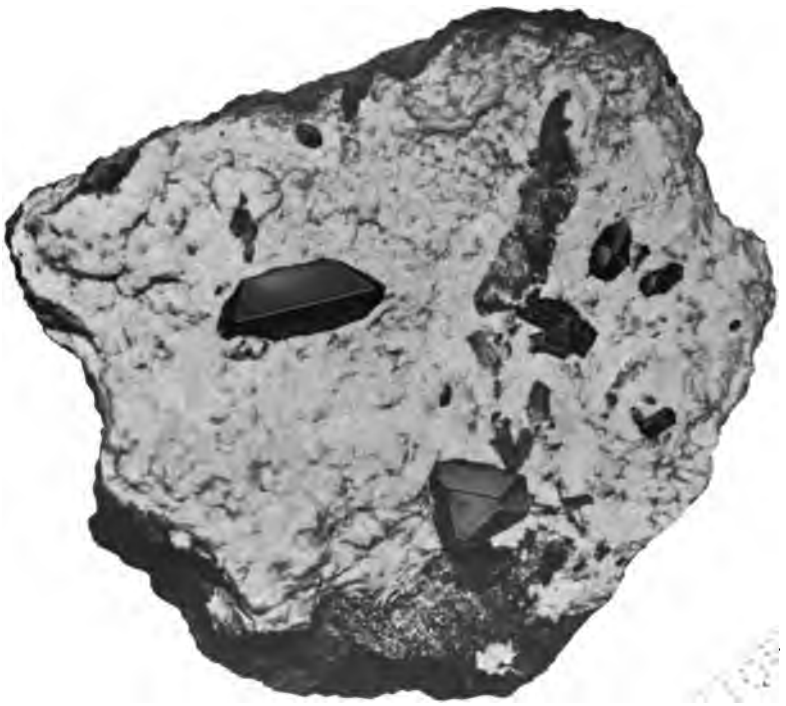
1 2 3 4



5

Benitoite.—1 and 2. Gem in ordinary reflected light, natural size; 3. in transmitted light, extraordinary ray; 4. in transmitted light, ordinary ray. 5. Crystals in matrix, ⅘ nat.

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$b(010)$ is always narrow and strongly striated vertically and difficult to get readings on. Its position in the prism zone is definite and its even truncation of the angle $110 \wedge 1\bar{1}0$ leaves no doubt as to its identity.

As a constituent form of the crystals g is quite definite and generally present, but its attitude is somewhat variable. It is always more or less curved and generally dull. While in general it lies in the zone of $(\bar{1}11)$ and $(\bar{3}11)$, it appears to be sometimes curved in such a way that its traces with $(\bar{1}11)$ and $(\bar{3}11)$ are not parallel, and in such cases the distance between these edges is always greater along the edge $g^3 \wedge g^4$ and diminishes outwards in both directions. Where most simply developed it is a narrow band and lies sensibly in the zones $\bar{1}11$-$\bar{3}11$, $\bar{2}21$-$\bar{2}\bar{2}1$ and $\bar{1}\bar{1}2$-$\bar{1}10$ corresponding to the symbol $(\bar{2}11)$; but where more broadly developed the lower portion approaches in attitude to $(\bar{9}44)$.

Measurements made on the poor reflections of the lower portions of curved faces gave

	Measured.		Calculated.	
	ϕ	ρ	ϕ	ρ
(1)	52° 07′	52° 49′	$(\bar{9}44) =$ 52° 28′	52° 58′
(2)	51 17	51 31	$(\bar{2}11) =$ 47 29	50 5
(3)	51 43	52 47		

Habit. By far the larger number of neptunite crystals are attached at one end and grow out as comparatively slender prisms six or eight times or even ten times as long as broad. A moderate number show development of faces at both ends of the prism axis, but the habit is always prismatic, and is somewhat similar to that described by Wallenström, but in the Greenland prismatic neptunite the orthodome is the most important terminal form, and occurs also in the first found prismatic type of the mineral described by Nordenskiöld. In the California neptunite as far as known both ortho- and clino-domes are entirely lacking.

The basal plane is always small and brilliant and in outline commonly developed obliquely to the symmetry plane; g is very commonly dull and p frequently so; o^4, $\bar{1}11$ is generally, s^2, $1\bar{1}1$ frequently and i^4, $\bar{1}12$ sometimes striated parallel to the edges of the diagonal zone $1\bar{1}0$-$1\bar{1}1$-001-$\bar{1}12$-$\bar{1}11$-$\bar{1}10$; o^3, $\bar{1}\bar{1}1$, i^3, $\bar{1}\bar{1}2$, s^1, 111 to edges of the corresponding zone, 110-001-$\bar{1}\bar{1}0$. The front pinacoid and the prism (110) are always present and the planeness

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of their surface is very generally impaired, *a* showing vertical striations and sometimes slight curvature horizontally, and *m* is striated both vertically and in the zone (001)-(110) respectively ($\bar{1}10$). The pyramid $r(\bar{2}21)$ occurs only on a minority of crystals and is generally small and usually bright.

A rather common type is illustrated in figure 1, plate 39, which was drawn from a doubly terminated crystal free from the matrix and 42 mm. long by 8 mm. wide. The slight curvature in *g* is not shown. This illustrates about the average proportional length of the prisms. It is very common for the front planes to be rather small and the back planes to cut much farther down on the prism. The width of *g* is very variable and the planes *p* are frequently the largest of the terminal planes.

Figure 2 is from a stout prism some 12 mm. wide and shows a high development of the unit pyramids. The *g* faces are narrow and the "edges" $g/\!\wedge p$ curved and of varying distance from the $o/\!\wedge g$ edges.

Figure 3 shows a peculiar asymmetric development and was drawn from a doubly terminated prism 8 mm. long by 3 mm. wide, though only the planes at one termination are shown. It illustrates the usual ways in which $r(\bar{2}21)$ appears, either as a small triangular face between *g* and the prisms, or less commonly as a rhomboidal form bounded by the prisms, and by *o* and *p* when *g* is narrow or absent.

Only one crystal of the type shown in figure 4 was found. It shows the front faces $s(111)$ largely developed and cutting down much farther on the prisms than the back faces. Both $i(\bar{1}12)$ and *g* are absent, and *r* and *p* occur as narrow strips bordering *o*.

Physical Characters.

Hardness between 5 and 6. Density 3.18-3.19. Cleavage perfect, prismatic parallel to $m(110)$, with normal angle of 80° 18′.

The crystals are black and lustrous; in thin sheets or splinters, deep blood red. Cleavage plates show strong pleochroism: **c** deep ocreous yellow to brownish red; **a** pale yellow to reddish yellow in thicker sections; $\mathfrak{c}'\wedge c = 14°5$.

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Chemical Characters.

It is practically insoluble in hydrochloric acid and may therefore be chemically separated from the natrolite matrix as is the case with the benitoite.

Professor Blasdale's quantitative analysis is here given, and for comparison, two made on the Greenland neptunite, the first by Flink, the second by Sjöström.[13]

	Neptunite (Greenland)		California Mineral	Molecular ratios for
	I	II	III	III
SiO_2	51.53	51.93	53.44	.820
TiO_2	18.13	17.45	17.18	.213
FeO	10.91	10.23	11.23	.230
MnO	4.97	5.32	1.78	
CaO	——	0.71	0.25	
MgO	0.49	——	1.82	
K_2O	4.88	5.71	5.39	.204
Na_2O	9.26	9.63	9.14	
	100.17	100.98	100.23	

He says "The results show a substantial agreement in the composition of the mineral from the two localities, the most marked differences apparently resulting from the substitution of magnesium and iron for some of the manganese in the Greenland specimens. Sjöström represents the composition of the mineral by the formula $ROR_2O.TiO_2.4SiO_2$ and the same form can be applied with equal degree of success to the new analysis."

NATROLITE.

Natrolite is the gangue in which the benitoite and neptunite occur, and it is also found in veinlets without associates.

Fracture of the solid vein-stone shows a mass of xenomorphic crystals exhibiting a good cleavage that yields more or less curved surfaces. The general texture is granular but with common development of radiate forms quite different from the usual radiate arrangement of natrolite and not showing such distinct straight-line boundaries to the components.

Where open spaces occur in the veins allowing the formation of crystal faces, peculiar aggregates are found entirely unlike the

[13] *Geol. Fören. Förh.*, 15 (1893), p. 393.

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ordinary natrolite. Instead of the usual prisms with square pyramidal terminations there are formed small roof-shaped ridges as shown in plate 34, commonly with curved or more strictly broken roof lines and coxcomb-like groups. These are made up of elements that are bounded by a basal plane and unit prism. The smaller angle of the prism generally projects out into the open cavity. In other words, the tendency is to place the *b* axis at right angles to the wall. The apex of the roof-shaped form is then a prism edge. The radiate groups are produced by laying the elements together along the diverging basal planes whose intersections are roughly parallel.

More complicated aggregates are common. In certain druses lined with greenish amphibole needles the natrolite occurs as small equant groups looking in the distance as if individual crystals perched on the ends of the amphibole fibres, as shown in figure 2, plate 35. A close examination shows them to be complex aggregates in which the tabular elements described above can frequently be observed. This mode of occurrence is undoubtedly closely related to the botryoidal groups which are occasionally found and which are illustrated in plate 36. Under the microscope the structure of the natrolite gangue is rather complex. As viewed on a fracture surface or in section, the radiate groups described show divergent strips that are elongated at right angles to the vertical axis. As the axis is perpendicular to the basal plane the elongation in thin section will always be optically negative. This is just the reverse of that usually seen in divergent natrolite groups and a positive elongation is generally looked upon as a character of diagnostic importance.[14]

In sections parallel to the base is often seen the twinning described by Lacroix,[15] with (110) as twinning plane forming, as it were, a sort of irregular mosaic when viewed with the aid of a gypsum plate.

A group of natrolite crystals, rare for this occurrence, was found showing the normal development of habit and planes. The

[14] Cf. Rosenbusch, *Mikoskopische Physiographie,* etc., Bd. I, 2 (1905), p. 178.
Lacroix, *Mineralogie de France,* Vol. II, p. 267.
[15] *Loc. cit.,* p. 265.

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Natrolite, crystalline aggregate, tabular habit. Natural size.

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Natrolite, crystal group, normal prismatic habit. Natural size.

Natrolite druse showing equant groups perched on soda amphibole fibers. Natural size.

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individuals are large—two to four centimeters long—with prism faces 6 to 10 mm. broad, and show a combination of the unit prism $m(110)$ and unit pyramid $o(111)$. The faces are somewhat dull, but they show a very perfect cleavage, yielding lustrous surfaces. A distinct zonal structure is present, appearing to the eye as layers of different degrees of translucency lying parallel to the faces of the external form. These prisms show straight extinction and in a section perpendicular to prism edges an acute positive bisectrix, the axial plane bisecting the cleavage at the obtuse angle, that is, $\|(010)$. It does not seem probable that these crystals formed under the same conditions as the natrolite matrix of the titano-silicates. The peculiarity of the prevailing habit may be considered as dependent on the unusual composition of the solutions giving rise to the benitoite and neptunite. No crystals of benitoite or neptunite were found with or near the group showing this prismatic habit. Plate 35, figure 1, is from a photograph of one of these prismatic groups.

A chemical analysis of the pure white benitoite matrix was made by Professor Blasdale showing it to be pure natrolite.

	Matrix.	Natrolite calculated.
SiO_2	47.69	47.49
Al_2O_3	27.14	26.79
Na_2O	15.74	16.28
H_2O	9.56	9.44
	100.13	100.00

A somewhat careful search failed to show the presence of even traces of titanium, barium, manganese, or potassium.

COPPER MINERALS.

In some parts of the deposit the copper sulphide chalcocite is not infrequent. It occurs enclosed in the natrolite in dark gray or black anhedral grains several millimeters in diameter. Occasionally on fractured surface it shows distinct and characteristic crystal outline, occurring then as a flat table with the trace of a hexagon elongated parallel to one pair of sides. It is to be considered an original mineral of the veins.

In the same part of the deposit is found the copper silicate chrysocolla. It occurs in small quantity as a stain or thin coating

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here and there, probably as a result of the alteration of the chalcocite, but also as individual grains 4-6 mm. across in the granular natrolite matrix. These may represent original chalcocite grains that have been replaced by solutions percolating through the natrolite and thus becoming charged with silica, but from the freshness of the surrounding natrolite and neighboring chalcocite it may be that some of the copper in the original solutions was held as silicate and separated out primarily as chrysocolla.

Both of these copper minerals occur side by side with the titano-silicates.

OTHER MINERALS.

Amphiboles.

Some of the drusy surfaces are coated with green or bluish green amphibole needles, and the natrolite and albite crystals often carry them in sufficient quantity to give a greenish or bluish tint. These amphiboles vary from place to place and even the same needle may show different optical properties along its length.

A common type is actinolite. This has been observed in thin needles growing out into open spaces as a newly formed mineral in the wall rock and in veins. Occasionally it develops as asbestos films or exceedingly fine hair-like bunches. It shows pleochroism in pale green and yellow, the **c** sometimes having a bluish tint. It gives a distinct sodium reaction in the blowpipe flame.

Another common amphibole is bluish green in color and shows under the microscope **a** greenish yellow, **b** gray violet, **c** bluish green. The axial plane is transverse to the plane of symmetry and the dispersion is so great that it shows no extinction in plane (010) with white light. The extinction for red light is about 25°-30°, for violet some 5° greater. Its properties would indicate a soda amphibole with considerable iron in the molecule —perhaps intermediate between crossite and crocidolite, but nearer the crossite type.

A member of the glaucophane group is sometimes present. **c** blue, **b** violet, **a** yellow; **c** Λ *c* about 8°.

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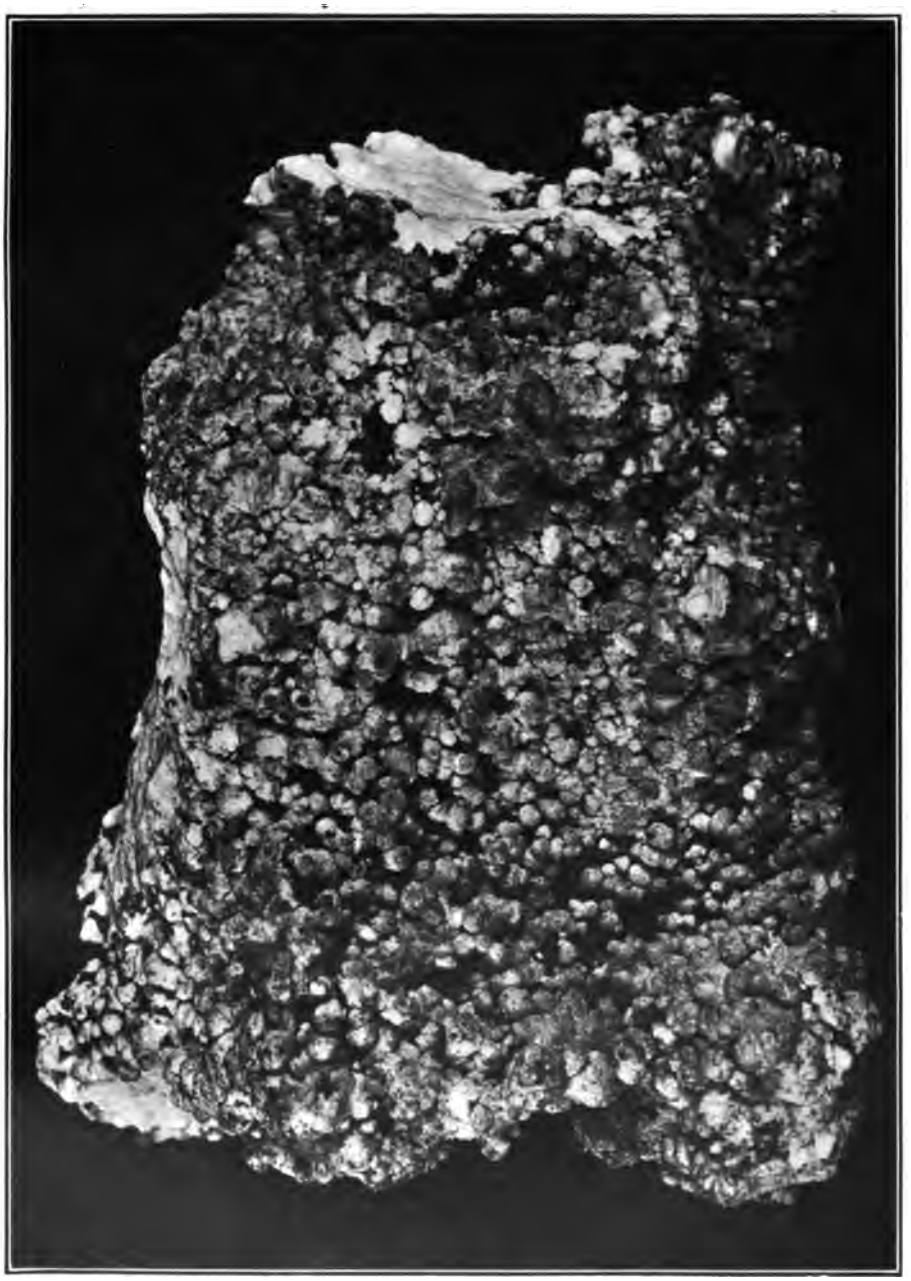

Natrolite, botryoidal aggregate. Slightly reduced.

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To get a more definite idea of the chemical nature of the amphibole occurring in the druses carrying the perched natrolites, a separation was attempted. The material is essentially of the type just described as related to crossite, but contained a small amount of actinolitic and other amphibole material in spots and zones on the crystals, and also a very small amount of natrolite that could not be entirely separated. Professor Blasdale's analysis follows:

	Amphibole of Druse	Crossite, North Berkeley (Smith)
SiO_2	52.94	55.02
Al_2O_3	3.76	4.75
Fe_2O_3	——	10.91
FeO*	13.40	9.45
MnO	1.44	trace
MgO	11.54	9.30
CaO	5.45	2.38
Na_2O	5.11	7.62
K_2O	0.43	0.27
H_2O at 110°	1.31	——
Ign	3.72	?
	98.67	99.70

*All Fe assumed to be ferrous.

Albite.

Albite has not been found in direct association with benitoite or neptunite. It is common in minute veins in some of the surrounding rock, where it is generally granular and determinable only by means of the microscope. But in places it is developed in druses in the zone of mineralization and appears as crystals 5 to 10 mm. long growing from the blue-green amphibole wall. These crystals are generally translucent grayish or greenish in hue, due to included amphibole fibres.

Most commonly the crystals are twinned according to the albite law. Simple twins are the rule, but sometimes there are several very thin polysynthetic lamellae intercalated between the two main halves of the twin. The habit is defined by the dominance of *M*, *M* (010); *l*, *l* (110); *T*, *T* ($1\bar{1}0$); *o*, *o* ($\bar{1}\bar{1}1$); *p*, *p* ($\bar{1}11$) and *P*, *P* (001). The forms are named in order of size. *M* is the largest though never so large as to produce a distinctly tabular habit, *T* and *o* about the same, and *P* distinctly smallest. The general mode of growth is such that the crystals are attached

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over the region that if completely developed would be occupied by the faces P and $\underline{P}$, where they form the salient angle, and over part or all of the area of l, $\underline{l}$ (110). The re-entrant angle between the bases is therefore uniformly presented towards the observer and the basal planes are very decidedly the most lustrous faces on the crystals. The faces o and p are very largely developed, being sometimes longer than M and $\underline{M}$ and the crystal appears prismatic parallel o, o, p, p.

These dominant faces are modified by the following: $f(130)$, z $(1\bar{3}0)$, η $(1\bar{2}0)$, c $(1\bar{1}1)$, x $(\bar{1}01)$, δ $(\bar{1}\bar{1}2)$, Θ $(\bar{1}\bar{3}1)$, u $(\bar{2}\bar{2}1)$. The form x shows an unusual lack of prominence, occurring as a very narrow strip. Of the others, u $(\bar{2}\bar{2}1)$ is a rather uncommon form for albite, and c $(1\bar{1}1)$ and η $(1\bar{2}0)$ are very rare. The former (c) is reported by Jeremejew[16] from the Lake Baikal region; the latter, η $(1\bar{2}0)$ by Klockmann from the Riesengebirge granitic rocks.[17] As far as known to the writer Θ $(\bar{1}\bar{3}1)$ has not been previously reported as occurring on albite. The form c is very narrow but bright; η, u and Θ are generally progressively broader in the order named, the last mentioned being sometimes over ½ millimeter wide. The relations of these planes are shown in figures 5 and 5a, plate 38, which were drawn from a crystal about 5 millimeters high.

The following measurements were obtained, the calculations being based on Brezina's elements for pure albite:

	Measured.				Calculated.			
	ϕ		ρ		ϕ		ρ	
$P(001)$	81°	56′	26°	50′	81°	51′	27°	01′
$M(010)$			set		0	00	90	00
$l(110)$	60	27	90	00	60	25	90	00
$T(1\bar{1}0)$	119	54	set		119	52	90	00
$\eta(1\bar{2}0)$	138	47	90	00	138	42	90	00
$f(130)$	30	16	90	00	30	23	90	00
$z(1\bar{3}0)$	149	47	90	00	149	44	90	00
$x(\bar{1}01)$	$\bar{8}0$	50	25	58	$\bar{8}0$	54	25	48
$c(1\bar{1}1)$	108	28	57	35	108	18	57	27
$o(\bar{1}\bar{1}1)$	$\bar{1}35$	26	34	07	$\bar{1}35$	21	34	11
$\delta(\bar{1}\bar{1}2)$	177	00	11	42	176	17	11	38
$\Theta(\bar{1}\bar{3}1)$	$\bar{1}63$	19	59	13	$\bar{1}63$	30	59	13
$u(\bar{2}\bar{2}1)$	$\bar{1}25$	30	60	50	$\bar{1}25$	26	60	50

[16] *Zeit. für Kryst.*, 32 (1900), on albite, pp. 494-495.

[17] *Zeit. d. deutschen geol. Gesell.*, 34 (1882), on albite, pp. 416-426. This form is characterized as doubtful by Dana, System of Mineralogy (1892), p. 328; and as "nicht ganz sicher" by Hintze in his Handbuch der Mineralogie, 2 (1897), p. 1447.

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$p(\bar{1}11)$ on lower side of twin was determined as being in zones $\bar{1}\bar{1}1$-$\bar{1}\bar{3}1$-010, and 001-$1\bar{1}0$.

The extinction on cleavage flakes parallel to (010) is +18°; on (001) +4°+.

Aegyrine.

At one point there was found in the albite a belt several inches long of stellate groups referred to aegyrine. The color is greenish black. The individuals, sometimes as much as 6 or 8 mm. long, do not show crystal form and are exceedingly thin in one dimension, corresponding to the tendency of aegyrine to form needles very flat parallel to (100). They were determined under the microscope by their high refractive index, negative elongation with maximum angle of extinction 2° or 3°; pleochroism, **a** deep grass green, **b** lighter green, **c** brown to yellow; absorption **a** > **b** > **c**. The needles melt readily before the blowpipe, with a strong sodium flame, to a black magnetic globule.

Calcite and Aragonite.

Crystallized calcium carbonate has not been observed in the benitoite-natrolite veins, but is not uncommon in the adjoining rocks, especially in the altered basic rocks on the south side. It occurs as stringers and bunches. While calcite is the more common form, specimens of aragonite were obtained in radiate groups of columns 1 to 4 mm. thick. They are translucent and have a slightly brownish tint and while not showing terminal planes, the prismatic and pinacoidal cleavages are well developed. They carry on their surfaces small, white, more opaque calcite rhombohedra.

Manganese dioxide.

Thin stringers and coatings of manganese dioxides are common in the country on the north side just below the cut. It generally shows the character of psilomelane and is frequently in fine globular and botryoidal aggregates.

While it may sometimes be found in the same hand-specimen that carries the benitoite veins, it does not actually occur in these veins in which the manganese is limited to the neptunite.

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COUNTRY IN WHICH THE VEINS ARE FORMED.

As already stated, the chief rock of the surrounding country is serpentine. This is of a type common in the Coast ranges and in general derived from the alteration of a peridotite. Small areas of a pyroxenic facies occur. Nowhere so far as known do the veins under discussion occur in actual contact with the serpentine, although it surrounds the deposit and is frequently not many yards distant from them.

The rocks immediately associated with the veins are all more or less altered, and this alteration is greatest close up to the zone of veination. In the less altered parts both igneous and sedimentary types are recognized. The more common type has in the field the usual appearance of the Franciscan greenstones. Under the microscope it is seen to have originally possessed a diabasic structure. In some specimens the augite is still largely intact. The feldspars however are recrystallized into a fine granular mass. Yet they often show very clearly by the outline of the granular areas the lath-shaped forms of the original feldspars and the relationship to the augites that characterize the diabase structure. Some titanite is present. In a somewhat altered specimen the augite is more or less altered into chlorite, while in the feldspathic layers small greenish or bluish needles are commencing to form in some cases actinolite, occasionally glaucophane, or some other geologically related amphibole. The new feldspar is at least in large part albite.

On the south hillslope below the east end of the deposit is a spheroidal gabbro. The grains and prisms of monoclinic pyroxene are in part altered to chlorite. The labradorite is more or less decomposed and otherwise altered and the rock is impregnated with calcite. It does not come in contact with the veins at any point.

Other rocks are found having the characteristics commonly displayed by the more altered Franciscan sandstones or greywackes. Under the microscope the light colored constituents which make up the bulk of the rock are seen to be entirely recrystallized into very fine granular aggregates. The original structure is preserved by the dark films of ferruginous or car-

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bonaceous matter that followed the lamination. The new feldspar as determined in several places is also albite. Throughout the rock small needles are beginning to develop, the more common one observed being actinolite. Some very small colorless ones also occur.

A peculiar rock occurs towards the western part of the zone. It is dark colored, aphanitic, dense and fine banded, as if from the effects of original lamination. Manganese dioxide stringers are common. Under the microscope it is seen to be a fine microcrystalline aggregate, consisting in part of dark patches made up largely of a brown mineral in short minute prisms with apparently straight extinction, negative elongation, high refractive index and moderately strong double refraction. In the preparations at hand it was not determinable. In parts veinlets and areas are numerous, carrying albite, chlorite, glaucophane, etc.

In the hope that its origin might be indicated by the chemical composition, Dr. Blasdale undertook the analysis with the following results.

SiO_2	54.51
Al_2O_3	6.55
Fe_2O_3*	19.34
MgO	3.47
CaO	5.90
Na_2O	5.95
K_2O	0.23
H_2O at 110°	0.74
H_2O ign	1.82
TiO_2	0.44
P_2O_5	0.30
MnO	0.52
	99.77

Specific gravity 3.104.

* Not able to effect complete decomposition of mineral for ferrous iron. At least 12 per cent. is ferric.

It is not entirely clear what type of rock this represents. The alumina is remarkably low and the iron high as associated with the other constituents. It has considerable similarity to the analysis of amphibole given on a previous page, and appears to point to considerable metasomatic alteration which conceals the original nature of the rock.

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The writer inclines to the belief that this rock was originally a facies of the Franciscan radiolarian chert. He has seen distinctly altered cherts that have a somewhat similar texture and mineral appearance under the microscope. The Franciscan cherts grade over insensibly into siliceous iron ores and in a number of localities have associated with them deposits of manganese dioxide. This would explain the high iron and low alumina content and the association with manganese stringers. Much or all of the soda and other oxides in part may have been introduced during the metamorphism, as in the case of certain crocidolite schists of the Coast Ranges which the writer has found to have been derived from ferruginous cherts by a similar process.[18]

Of the rocks described as associated with the veins the greenstone (altered diabase) is the most abundant and the one most commonly in contact with the veins in moderately altered condition—especially towards the east end. On approaching the central part of the zone of veination, however, the alteration increases very greatly, the original pyroxenic constituents disappear and the chief constituents are the new-formed amphiboles. The old structures are entirely lost. In part we may refer to the material as soda-amphibole schist.

A still further alteration is caused by the leaching out of the feldspathic constituents, leaving the rock in a more or less porous condition, as occurs on the left side of the cut shown in plate 32.

This rather porous rock near the veins may be thoroughly impregnated with natrolite for a fraction of an inch or several inches from the vein; also it is in this rock that the spaces occur covered with free-growing amphibole needles on which the natrolite groups are perched as already described.

SEQUENCE OF EVENTS.

The field relations and lithologic characteristics indicate that the rocks in which the benitoite-bearing veins occur are a detached mass of the Franciscan series, showing both igneous and sedimentary facies, that was included in the serpentine at the time of its intrusion.

[18] Louderback and Sharwood: *Bull. Geol. Soc. Am.*, 18 (1906), abstract p. 659.

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The rocks of the inclusion have all suffered more or less alteration affecting throughout the feldspathic constituents and characterized by the production of newly formed albite and, as the alteration proceeds, by the production of soda-bearing amphiboles from the ferro-magnesian constituents. Both the igneous and sedimentary types of the inclusion share in the alteration, which is remarkable in that the central portions are more strongly affected than the periphery. This can be explained by considering that emanations from below passed upward through the central portions of the rock-mass, and diffused out into the peripheral portions. Open channels may have existed in this central avenue, for it must have been an easier pathway than either the peripheral portions or the rock beyond. But if so the conditions at that time were not favorable to deposition along such channels. Furthermore, the extent and character of the alterations cannot be accounted for by such diffusion as often takes place in the formation of veins. One would expect the pressure to have been rather high and the temperature of the rocks undergoing alteration at least a few hundred degrees above the normal to favor the wide diffusion and production of albite and the amphiboles.

At least towards the end of this period of metamorphism we have the leaching of feldspathic material along portions of the central tract that produces the porous amphibole rock and the drusy spaces lined with amphibole needles in which the sodium-aluminum silicates are later deposited. This may be the same solution that, diffusing farther into the rocks, causes the recrystallization.

The first deposition along the zone of veination is probably that of albite, which is separated out in crystals over and about the amphibole druses and is accompanied at least in one place by aegyrine. Only a comparatively slight change is necessary to change a solution from a condition where it will slowly take up albite to one in which it will slowly deposit it in small quantity.

Before the natrolite deposition takes place important changes must have been brought about. The action is one of active deposition and is limited to the vein except where the wall-rock is porous. It is then impregnated for a short depth with natrolite and sealed, and the deposition in the vein continues with no

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further interchange or passage of material from or to the rocks. The setting up of active deposition, the stopping of metamorphogenic diffusion into the wall-rock, and the substitution of natrolite for albite as the precipitated molecule, all point to a marked lowering of temperature both of ascending solutions and of the country rock.

The benitoite and neptunite do not appear anywhere to follow the natrolite into the wall-rock. In a few places the neptunite appears to be partially surrounded at its base with amphibole-natrolite matrix but it is practically limited to the confines of the vein proper. Both benitoite and neptunite are attached directly to the wall so that they often commence to deposit before the wall received any coating of natrolite. They also occur in the central portion of the vein entirely surrounded by natrolite, showing that at these points the latter commenced depositing first. They also occur in the natrolite druses and project freely from the surface, showing that they were among the last materials to separate. We conclude therefore that benitoite, neptunite, and natrolite were deposited contemporaneously throughout the period of vein filling.

The order of crystallizing power—the crystalloblastic order—arranged in decreasing magnitude is neptunite, benitoite, natrolite. Natrolite is found in abundance surrounding neptunite and benitoite, molding itself to suit their form and showing the smooth surfaces of their imprint when separated. A few cases were observed where benitoite crystals are pierced by neptunite prisms or have partially grown around them.

The next events recognized are those of descending solutions, decomposition, etching, limonite coatings, etc., as already referred to elsewhere.

DISTRIBUTION OF MINERALS IN VEINS.

The workings are so shallow at the mine that there are no data at hand to indicate the distribution of the various minerals with depth. But it is of some interest to note that the distribution is not uniform along the surface. The benitoite is most abundant along the east central portion of the zone of veination. Passing eastward the titano-silicates decrease in abundance until the

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stringers, as judged in the outcrops, appear to contain nothing but natrolite and then play out and disappear.

Going westward the proportion of neptunite to benitoite increases until the latter practically disappears before the stringers die out in that direction.

THE RELATION TO THE SERPENTINE.

It would be interesting to determine whether the serpentine intrusion has had any direct effect on the production of the phenomena described. General considerations seem to the writer to indicate that it had.

The most suggestive characters of the deposit in this connection are perhaps the similarity in nature of the general metamorphism of the enclosing rock-lens to the more active alteration in immediate proximity to the vein on the one hand; and on the other hand the correspondence of the albitic alteration, the albite stringers of the country, the albite of the thin zone, and the natrolite in the benitoite veins which are all related chemically and by field relations. In other words, the general rock changes which seem to demand a general elevated temperature for their consummation, appear genetically related forerunners of the local action along the veins. Such a general elevation of temperature was undoubtedly supplied by the peridotite intrusion, and that occasion is most naturally taken as the period of metamorphism.

As regards the more extreme metasomatosis and later mineralization, it would seem that the rocks of the included mass were more favorable to the production and maintenance of channels than the surrounding peridotite, and acted as a vent pipe for the escape of solutions from the more highly heated lower portions of the peridotite mass to the overlying rocks, or possibly to the surface.

In considering the possibility of an origin of the deposit previous to the peridotite intrusion, the close relationship of the distribution of the veins and the present form of the included mass is suggestive. The veins run along in the direction of elongation of the lens and become smaller, less mineral-bearing and play out just before reaching the serpentine in either direction.

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GENERAL DISCUSSION.

The Franciscan series extends with various interruptions for about six hundred miles along the Coast Ranges of California and Oregon and in it and its associated eruptives are found a very great number of occurrences of vein deposits that lie among similar surroundings, and a comparison of these with the deposit now under consideration yields some general analogies along with the striking differences.

Very often in traversing the serpentine areas, so frequently associated with the Franciscan, we come across included masses of partly recrystallized basic rocks or irregular areas or lenses of glaucophane, hornblende, or other basic schists. These are often cut by veins of quartz, but of particular interest in the present connection are the abundant veins of albite. Natrolite, so far as known to the writer, has not been found under these conditions except at the benitoite locality, but the analogous albite veins are very common.

Titanium is often found in the recrystallized rock, occasionally in the veins, and occurs most commonly as titanite, sometimes as rutile.

While minerals containing potassium (usually muscovite), magnesium and iron (such as chlorite or more rarely talc) are also found in veins cutting such rocks, an association representing so many metallic elements in essential quantities as occur in the benitoite veins is exceptional: sodium, potassium, magnesium, iron, manganese, copper, aluminum, barium. With this variety it seems peculiar that calcium is practically absent within the veins proper. It is found generally in the veins in the schists as lawsonite or the amphiboles.

The occurrence of barium as an essential constituent is without precedent. The only barium mineral that the writer has found associated with such formations is barite in veins in the serpentine of Mt. Diablo. While suggestive of the presence and possible concentration of barium in such rocks, it is not an analogous occurrence.

Apart from the chemical differences, a comparison of the chief gangue materials, albite and natrolite, would indicate that

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the benitoite-bearing veins are exceptional in the lower temperature and perhaps more moderate pressure under which they were formed. The crystallization of complex and highly acid titanosilicates at the comparatively low temperature suitable for the production of natrolite demand the presence and activity of crystallizing agents (*agents mineralisateurs*) whose nature is not indicated by an analysis of the vein materials.

RECENT PAPERS.

A. F. Rogers: Note on the Crystal Form of Benitoite. *Science* n.s., 28 (1908), p. 616. He gets an average of 40° 10′ for the pole angle of the unit pyramid. He discusses the possible symmetry and inclines to the ditrigonal bi-pyramidal class.

W. E. Ford: Neptunite Crystals from San Benito County, California. *Am. Jour. Sci.* (4) 27 (1909), pp. 235-240, 8 figs. Describes the crystallography and optical properties of neptunite. Finds optic axial plane in plane of symmetry; $c \wedge \mathfrak{c} = 24°$; $b = \mathfrak{b}$; $\mathfrak{a}$ yellow, $\mathfrak{b}$ red, $\mathfrak{c}$ red. $\beta = 1.7$; $2V = 48° 40'$; optically +. Dispersion of optic axes $v > \rho$.

The common habit described by Ford is practically the same as that described by the writer; the less usual types are somewhat different. He notes the form g as new, and the drawings for this paper were changed to adopt this symbol. r was not reported.

Received May 19, 1909.

SUPPLEMENTARY NOTES.

To the proof of the above paper the writer is permitted to add the following notes on contributions to the study of benitoite and neptunite during the past summer.

The symmetry of benitoite. The writer notes that no evidence has been published unfavorable to the view of the strictly trigonal[19] symmetry of benitoite presented by the writer in the

[19] Not rhombohedral, as the writer is reported to have said, in the Referat of his paper, *Zeit. für Kryst. u. Min.*, 46 (1909) pp. 386-387. In the original paper (*loc. cit.* p. 150) he says "It crystallizes in the hexagonal system, trigonal division. The observed forms are the basal plane, the plus and minus trigonal pyramid and the corresponding trigonal prisms. . . . The development of faces at one end of the principal axis always corresponds so well with those at the other, that it gives the impression that the horizontal plane of symmetry is present." Trigonal bipyramids and corresponding trigonal prisms can only occur in the ditrigonal bipyramidal and in the trigonal bipyramidal symmetry classes in which the rhombohedra are not possible, and the Referent therefore misrepresented the writer's view of the symmetry relations when he wrote:

p. 386 line 4 from bottom, rhomboëdrisch for trigonal
Rhomboëder for trigonale Pyramiden
line 3 " " Rhomboëder for trigonale Pyramide.

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preliminary paper, and in particular its reference to the ditrigonal bipyramidal group announced by him at the December, 1907, meeting of the Geological Society of America, chiefly on the basis of the etch figures. Recently C. Palache and C. Hlawatsch have independently arrived at the same conclusion, the former[20] basing his conclusion on the hexagonal development of the second order forms, $(11\bar{2}0)$ and $(22\bar{4}1)$ and the latter[21] on the same ground and from a consideration of the etch figures. Hlawatsch also discovers[22] certain natural irregularities on the faces of the negative (Louderback) pyramid which might indicate a pseudo-trigonal symmetry (possibly orthorhombic hemimorphic trillings), but finally decides in favor of the trigonal.

Crystal constants of benitoite. The average angle $(0001) \wedge (10\bar{1}1)$ is given by Rogers as 40° 10′; Palache 40° 12′; Hlawatsch 40° 14′, the value arrived at by the writer on his earlier material; Louderback 40° 18′; Baumhauer[23] 40° 19′ 37½″. These yield $c:a$=0.7310 (for 40° 10′); 0.7319 (P.); 0.7327 (H.); 0.7344 (L.); 0.7351 (B.). Palache apparently adopts the reference axes (G_2) and gives p_0=.4879 corresponding to p_0=.4896 (L.); Hlawatsch selects (G_1) and gives p_0=.8461 corresponding to p_0=.8480 (L.).

In his table of Goldschmidt elements (G_1) Hlawatsch gives c=0.7327 when, following Goldschmidt's practice, it should be c=1.2690[24] lg c=0.10349, corresponding to the writer's c=1.2720.

Crystal forms of benitoite. The following table gives the correspondences of planes reported on benitoite by the various writers:

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[20] Palache, C. Note on Crystal Form of Benitoite. *Am. Jour. Sci.* (4), 27 (1909), p. 398; also German translation with slight and unessential additions, *Zeit. für Kryst. u. Min.*, 46 (1909), p. 379.

[21] Hlawatsch, C. Die Krystallform des Benitoit. *Centralblatt für Min., Geol. u. Pal.*, 1909, pp. 293-302 and p. 410. Also *Zeit. für Kryst. u. Min.*, 46 (1909), p. 602.

[22] *Loc. cit.*, pp. 300-301.

[23] Baumhauer, H. Ueber die Winkelverhältnisse des Benitoit. *Centralblatt für Min., Geol. u. Pal.*, 1909, pp. 592-594. Results of measurements on some very small crystals giving simple, good reflections..

[24] The value given by Hlawatsch is, for (G_1), c, but it is Goldschmidt's practice to use uniformly in his Winkeltabellen $\overset{(10)}{c}$ and report it simply as $\overset{(1)}{c}$. $\overset{(1)}{c}=\overset{(10)}{c}\sqrt{3}$. The value 1.2708 for apatite given in his Winkeltabellen is therefore not a "Druckfehler," as stated by Hlawatsch (*loc. cit.*, p. 299) and should appear as printed.

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Louderback.	Palache.	Hlawatsch.	Rogers.
$c(0001)$	$c(0001)$	$c(0001)$	(0001)
$a(11\bar{2}0)$	$a(11\bar{2}0)$	$a(11\bar{2}0)$	.....
$m(10\bar{1}0)$	$\mu(01\bar{1}0)$	$m(01\bar{1}0)$	$(01\bar{1}0)$
$\mu(01\bar{1}0)$	$m(10\bar{1}0)$	$M(10\bar{1}0)$	$(10\bar{1}0)$
$p(10\bar{1}1)$	$\pi(01\bar{1}1)$	$p(01\bar{1}1)$	$(01\bar{1}1)$
$\pi(01\bar{1}1)$	$p(10\bar{1}1)$	$P(10\bar{1}1)$	$(10\bar{1}1)$
$r(10\bar{1}2)$	$e(01\bar{1}2)$	$r(01\bar{1}2)$	$(01\bar{1}2)$
$d(22\bar{4}1)$	$x(22\bar{4}1)$	$d(22\bar{4}1)$	.....

Hlawatsch gives also $D(22\bar{4}3)$ as dull faces on one crystal, and also $s(11\bar{2}1)$ and $a(3.\bar{1}9.16.12)$. These are reported as "unsichere Flächen," and of the two latter he says, p. 296, "es können leicht Abformungen von den begleitenden Neptunit Kristallen gewesen sein." This is easily possible as neptunite has the stronger crystallizing force and benitoite is often found molded against or around it. The writer's form of doubtful index $x=(\bar{1}0.1.9.10)$ is not reported by the others.

The fundamental form of benitoite. The three authors cited above agree in selecting μ (Louderback) as the positive unit pyramid and their positive forms correspond to the writer's negative forms and vice versa. While they do not discuss the point, they were apparently led to the selection by the fact that this form is usually developed at this locality in broader faces than the complementary pyramid. The designation of positive unit form ought to be applied whenever possible to the physically most fundamental pyramid. It is well known that the relative size of faces is a very variable matter and commonly determined by the character of the solution from which the crystal separates. Calcite is an excellent example. The cleavage rhombohedron is very appropriately taken as the positive unit form but other rhombohedra both positive and negative are often developed in larger faces and the fundamental rhombohedron is frequently not present among the growth planes at all. Furthermore negative rhombohedra may dominate the positive even to their complete exclusion. The peculiar symmetry of the trigonal pyramids is such that a cleavage if present would be of no value in discrimination, for m^1 is parallel to $\underline{\mu}^4$; $\mu^2 \parallel \underline{m}^5$, etcetera.[25]

[25] Numbers superscript refer to sextants counted clockwise; a bar below signifies a lower dodecant, the upper one being unmarked, as used by Goldschmidt.

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The following consideration decided the writer in the choice of the positive unit form and seems to him to indicate its more fundamental character than the complementary pyramid of the same parameters. In growth the positive pyramid produces more perfect planes and more brilliant faces, the negative pyramid showing most commonly uneven, curved, influenced and otherwise less perfect forms even when it is areally about equal to the positive form. In the attack of corrosive agents, the positive pyramid is much more resistant than the negative. In concentrated hydrofluoric acid the negative faces immediately become dull and are rapidly corroded, the positive planes remain bright and show the production of small well-formed etch figures. The positive faces must eventually be attacked over their whole surface but this was not observed during the progress of the experiment which lasted at least two hundred times and more as long as it took to entirely destroy the original surface of the negative pyramids. That this same relative resistance of the positive planes exists under very varying conditions is shown by the facts that it was observed (1) in the natural weathering process, (2) in hydrofluoric acid, both hot and cold, concentrated and dilute, and (3) in fused caustic potash.

Goldschmidt and Wright[26] in their work on that form-rich mineral, calcite, found that the more fundamental planes give the best etch figures, and suggest it as a possible general method for their determination. In benitoite there is a very marked superiority in this respect of the form selected as positive by the writer over the corresponding negative form. Altogether, then, the different lines of evidence are consistent and definite and indicate the writer's positive unit form as the more fundamental.

Refractive index of benitoite. Hlawatsch has also determined the refractive index of benitoite by the prism method (*loc. cit.*, p. 301) with results almost identical with the writer's.

	Hlawatsch.	Louderback.
ω	1.756	1.757
ϵ	1.802	1.804

[26] *Neues Jahrb. für Mineral., etc.* (1903), Beilage-Band 17, p. 365.

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Neptunite.[27] W. M. Bradley has recently published the following analyses of the San Benito neptunite[28] with values very close to those given by Blasdale.

	Bradley				Blasdale	
	I	II	Mean	Mol. Ratios	Mean	Mol. Ratios
SiO_2	52.91	52.83	52.87	.875	53.44	.820
TiO_2	17.77	17.89	17.82	.222	17.18	.213
FeO	11.54	11.83	11.69	.235	11.23	.230
MnO	0.82	0.88	0.85		1.78	
CaO	1.59	1.53	1.56		0.25	
MgO	1.41	1.48	1.44		1.82	
K_2O	5.11	5.06	5.08	.208	5.39	.204
Na_2O	9.83	9.28	9.56		9.14	
	100.98	100.78	100.88		100.23	

Albite. A recent abstract in the Zeitschrift für Krystallographie[29] shows that Dreyer and Goldschmidt have studied some remarkably form-rich albites from Greenland, in which are found among others certain of the rare forms and the supposedly new form on the San Benito albite: $u(\bar{2}\bar{2}1)=u(\bar{2}\bar{2}1)$ (S.B.); $a(1\bar{2}0)=\eta(1\bar{2}0)$ (S.B., following Klockmann); $\eta(\bar{1}\bar{3}1)=\Theta(\bar{1}\bar{3}1)$ (S.B.). It may be noted that the angles for the San Benito albite reported by the writer agree more closely with the values calculated by Dreyer and Goldschmidt from their newly determined elements, than they do with the angles calculated from the Brezina elements given above (p. 362).

	Measured San Benito Albite		Calculated (Elements of Dreyer & Goldschmidt)	
	ϕ	ρ	ϕ	ρ
$P(001)$	81° 56′	26° 50′	81° 59	26° 51′
$l(110)$	60 27	90 00	60 38	90 00
$T(1\bar{1}0)$	119 54	90 00	120 04	90 00
$\eta(1\bar{2}0)$	138 47	90 00	138 59	90 00
$f(130)$	30 16	90 00	30 24	90 00
$z(1\bar{3}0)$	149 47	90 00	149 50	90 00
$r(\bar{1}01)$	$\bar{8}0$ 50	25 58	$\bar{8}0$ 44	26 00
$e(1\bar{1}1)$	108 28	57 35	108 34	57 26
$o(\bar{1}\bar{1}1)$	$\bar{1}35$ 26	34 07	$\bar{1}35$ 3	34 16
$\delta(\bar{1}\bar{1}2)$	177 00	11 42	177 14	11 39
$\Theta(\bar{1}\bar{3}1)$	$\bar{1}63$ 19	59 13	$\bar{1}63$ 17	59 8

[27] A German translation of Ford's paper on neptunite cited above occurs in *Zeit. für Kryst. u. Min.*, 46 (1909), pp. 321-325.

[28] *Am. Jour. Sci.* (4), 28 (1909), pp. 15-16. Also German translation of the same, *Zeit. für Kryst. u. Min.*, 46 (1909), pp. 516-517.

[29] Über Albit von Grönland: *Meddelelser am Grönland*, 34 (1907), 1-60. Ref. *Zeit. für Kryst. u. Min.*, 46 (1909), p. 605.

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Joaquinite. Associated with the minerals of the benitoite-bearing veins is occasionally found a honey yellow or light brown substance in small generally individual crystals or crystal grains rarely over one millimeter in diameter which is believed to be a new mineral. On account of its rarity, minute size and the general imperfectness of its crystals, its investigation has been attended with considerable difficulty. A preliminary statement of its properties is here presented. Some recently acquired material containing this mineral is being worked over for its separation with a view to a more complete study and for purposes of a quantitative chemical analysis which has not heretofore been possible and the writer expects to present a more complete description of the mineral in the near future.

The crystals are generally equant, occasionally slightly tabular, and always show two parallel almost square smooth faces, the other larger faces being strongly striated. The evidence so far obtained indicates that the mineral is orthorhombic and the two broad smooth faces are taken as the basal plane, and the eight lateral inclined planes, the only pyramidal planes so far observed, are taken as the unit pyramid. We have the combination $c(001)$ and $p(111)$ and on one crystal $a(100)$. The axial ratios based on the position angles for p of $\phi=76° 37'$, $\rho=47° 25'$ are $a:b:c=2.8440:1:0.9190$.

ELEMENTS.

$a=0.9190$	lg $a=9.96332$	lg $a_o=9.50939$	lg $p_o=0.49061$	$a_o=0.3231$ | $p_o=3.0946$
$c=2.8440$	lg $c=0.45393$	lg $b_o=9.54607$	lg $q_o=0.45393$	$b_o=0.3516$ | $q_o=2.8440$

Two crystals and part of a third were studied goniometrically, but only one of the crystals was satisfactory. Measurement is interfered with in two ways. The basal faces are commonly somewhat curved (concave), and the pyramid faces are strongly striated horizontally. As a result measurements could not be trusted on two of the crystals within one or two degrees. On one of the crystals the basal faces are quite plane and can be set very satisfactorily within a few minutes, and the majority of the pyramid faces show plane strips broad enough to get definite reflections. For this crystal I am indebted to Mr. R. M. Wilke of Palo Alto.

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ρ measured from c as pole face

p^1 76° 35′	p^1 striated blurred reflection
p^2 train 72° 56′-76° 20′	p^2 103° 22′ supplem. 76° 38′
p^3 76° 24′	p^3 striated, blurred band of light
p^4 76° 30′	p^4 103° 22′ supplem. 76° 38′

c as pole face

p^1 103° 15′ supplem. 76° 45′
p^2 103° 31′ to 40′ supplem. 76° 20-29′
p^3 103° 10′ supplem. 76° 50′
p^4 103° 12′ supplem. 76° 48′
average ρ=76° 37′
extremes 76° 20′-76° 50′

2ϕ measured 94° 52′, 94° 43′, 95° 01′, 94° 47′.

Average 94° 51′ or ϕ=47° 25′.

The pinacoid a was found on this crystal as a minute rhombus truncating the front and back solid angle of the four p faces, the signal was very faint and could not be set within 8 or 10 minutes.

	ϕ	ρ
Measured	89° 50′	89° 42′
Calculated	90° 00′	90° 00′

Cleavage is not distinct but appears to exist parallel to the basal plane and even less distinct perpendicular to it (possibly parallel to the two pinacoids). Whenever cleavage cracks appear under the microscope, the extinction is always straight with respect to them.

The optical orientation is $\mathfrak{a}$=a, $\mathfrak{b}$=b, $\mathfrak{c}$=c. $\mathfrak{c}$ is the acute bisectrix and in convergent light in sections perpendicular to the acute bisectrix (basal section), the optic axes emerge just at the edge of the field.

The refractive index is high (>1.73) and the double refraction strong. The mineral is transparent and has a honey yellow to brownish yellow color in fair sized fragments, very pale and transparent in thin section. In thicker pieces pleochroism is visible, $\mathfrak{c}$ ocreous or reddish yellow, $\mathfrak{b}$ light yellow, $\mathfrak{a}$ similar to $\mathfrak{b}$ but slightly paler. Absorption $\mathfrak{c}>\mathfrak{b}>\mathfrak{a}$. Hardness greater than glass (5.5); density determined on the largest crystal, between 3.85 and 3.9. Heated in closed tube it becomes paler colored.

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loses luster in part and yields a little water but does not fuse. Fuses readily in lower part of bunsen flame (2.5) with intumescence to a brown glass, practically colorless in thin bubbles.

It resists hot hydrochloric and nitric acids and may therefore be separated from the natrolite matrix by these agents. It is easily attacked by hydrofluoric acid which leaves a white film of decomposition products on its surface.

Qualitative chemical tests have shown the presence in reasonable quantity of silica, titanium and calcium. Iron is also present and probably determines the color.

When first observed in small particles without definite crystal form the mineral was thought by the writer to be titanite. It answers to all the tests usually applied to titanite in small irregular particles in thin sections. In particular may be mentioned its color, high refractive index, strong double refraction, biaxial positive character, its pleochroic colors and absorption scheme, the tests for silica, titanium, and calcium. Its fusibility is exceptionally low and its density somewhat higher than the usual range of titanite. The crystal form is most distinctive. It has a characteristic orthorhombic habit unlike any of the titanites hitherto described. So very different in their general appearance however are the various habits of titanite that already in its history it has been given a number of different names. It seemed possible then that this might be a new and pseudo-orthorhombic habit of this protean mineral. After considering various possible orientations, the closest approximation was found, in considering the apparent basal plane to be $x(102)$ and the symmetry plane to bisect the obtuse angles of the pyramid. This would give the proper optical orientation, as in titanite $\mathfrak{c}$ is almost perpendicular to x and lies in the symmetry plane. In this arrangement the two back faces (p^3, p^4) and the front faces (p^1, p^2 as described above) must belong to different forms and would be expected to show some systematic difference in their angular relation to x and in the angles where they meet in the plane of symmetry. If orthorhombic each set of angles should have the same values. An examination of the detailed figures given above will show that the differences are only a few minutes and that the slight variations are not systematic or symmetrical

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in either set. The measurements therefore indicate orthorhombic symmetry.

The pyramid faces which in a mineral of so simple a habit as is here shown would be expected to have rather simple indices, give approximations to only very complicated titanite forms. The nearest *simple* possible titanite forms are $(\bar{2}21)$ and $(\bar{3}44)$ with $x\wedge(\bar{2}21)=70°\ 37'$, $x\wedge(\bar{3}34)=76°\ 37'$ the measured value being 76° 37′. The coincidence of the last figures is shown to have no meaning, as ϕ^4-ϕ^3 referred to x as pole is 79° 15′ in titanite, 85° 9′ measured. A closer approximation would be $(\bar{3}54)$ and $(\bar{1}7\ 13\ 8)$. As regards the form called a above, the nearest approximation, with simple index, is titanite $(\bar{1}01)$ where $x\wedge(\bar{1}01)$ is 86° 56′, measured 89° 42′ orthorhombic should be 90° 00′. A closer titanite approximation would be $(\bar{1}7\ 0\ 16)$.

The attempt to make this crystal combination a habit of titanite is not successful and leads to very improbable results, while all of its properties so far determined consistently fit into the orthorhombic scheme. It may be noted here that under the microscope its most marked divergence from titanite is its inferior cleavage and straight extinction wherever cleavage cracks are observable.

This mineral may contain some other elements not shown in the preliminary microchemical tests, but it may also be a dimorphous form of titanite, or an orthorhombic end member of an isomorphous series.

The name is taken from the ridge (primarily anticlinal component) of the Diablo range on which the mineral occurs. The ridge received its name from the prominent Joaquin rocks—a landmark of the region.[30] It also borders the great San Joaquin valley.

Joaquinite is found enclosed in the natrolite, both at the edge of the veinlets and touching the wall rock, and also in the central portion of the vein. It is also found enclosed in the neptunite and seems especially to occur in those parts of the deposit rich in neptunite. Both the natrolite and neptunite are molded about it xenomorphically.

[30] See further Arnold and Anderson, *Bull. U. S. Geol. Survey*, No. 357 (1908), 13.

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Octahedrite. Palache in the paper cited above reports octahedrite as occurring in the benitoite-natrolite veins and gives the following description. "It appears in groups of pale-brown crystals, combinations of unit pyramid and base; the crystals are small and present facetted and curved faces so that they could not be measured but chemical tests showed the presence of titanic oxide alone." The writer has not observed octahedrite in any of the specimens he has studied and suggests that the mineral reported by Palache is the same as that described in the preceding section. The brief description fits perfectly except for the negative chemical evidence.

Issued December 24, 1909.

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EXPLANATION OF PLATE 37.

BENITOITE.

1. Very common habit: $c(0001)$, $p(10\bar{1}1)$, $\pi(0\bar{1}11)$, $m(10\bar{1}0)$, $\mu(0\bar{1}10)$.

2. Common habit with minute or no basal plane. The diminution of the basal plane is practically always accompanied by diminution of the positive pyramid.

3. A rather common habit, where $p(10\bar{1}1)$ intersects $c(0001)$ producing a hexagonal outline on the base, very rarely approaching an even development of positive and negative planes and giving a pseudo-hexagonal habit.

4. This figure without x is a type of a fairly common habit in which the $\pi\wedge\pi$ edges are truncated by $r(10\bar{1}2)$. The form x, of doubtful index, here taken as $(\bar{1}0.1.9.10)$, occurs on but a few crystals and was observed complete only about one terminal of a lateral symmetry axis, though here represented complete for the three axes.

5. Diagrammatic representation of etch figures. The planes of the upper half of a crystal are supposed rotated about their upper horizontal edges until they all lie in the plane of $c(0001)$. Where differently shaped figures appear on the same form they represent the more common types and variations, or the effects produced by distinct development of internal planes. The broken lines represent the traces of the lateral planes of symmetry.

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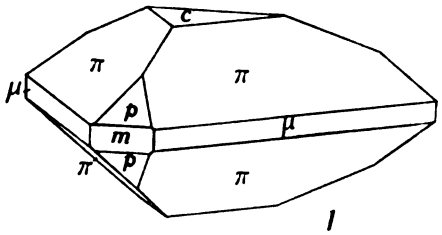

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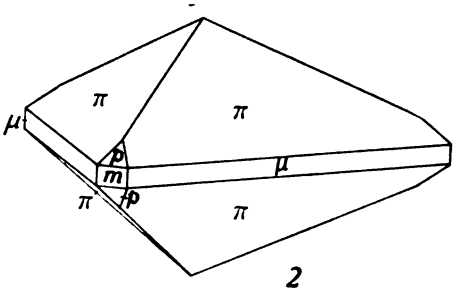

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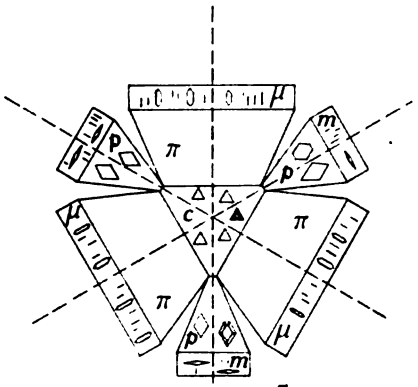

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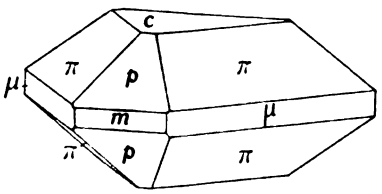

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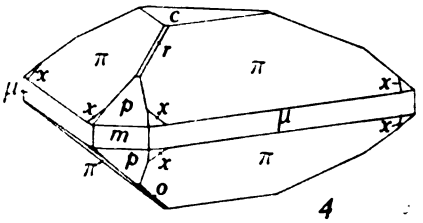

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EXPLANATION OF PLATE 38.

BENITOITE.

Planes shown: $c(0001)$, $a(11\bar{2}0)$, $m(10\bar{1}0)$, $\mu(01\bar{1}0)$, $p(10\bar{1}1)$, $\pi(01\bar{1}1)$, $d(22\bar{4}1)$.

1. Habit characterized by great development of the negative prism μ and found on a number of crystals.

2. Habit characterized by great development of the positive prism m. It is in general not uncommon for m to be broader parallel to the vertical axis than μ.

3. Habit characterized by second order forms d and a found with but slight variation in 10 crystals in a lot of 500 examined. The oscillatory striations between c and p are often found instead of $r(10\bar{1}2)$ and appeared in front upper sectant of crystal from which the drawing was made.

4. Detail of part of a crystal showing a coarse development of the oscillatory growth zone between c and p. Of two crystals on which this coarse development was found, one had the second order hexagonal prism a (as figured) without d, and the other d without a.

ALBITE.

5, 5a. Albite in simple albite twin from druse. $P(001)$, $M(010)$, $l(110)$, $T(1\bar{1}0)$, $\eta(1\bar{2}0)$, $f(130)$, $z(1\bar{3}0)$, $x(\bar{1}01)$, $c(1\bar{1}1)$, $o(\bar{1}\bar{1}1)$, $\delta(\bar{1}\bar{1}2)$, $\Theta(\bar{3}\bar{1}1)$, $u(\bar{2}\bar{2}1)$.

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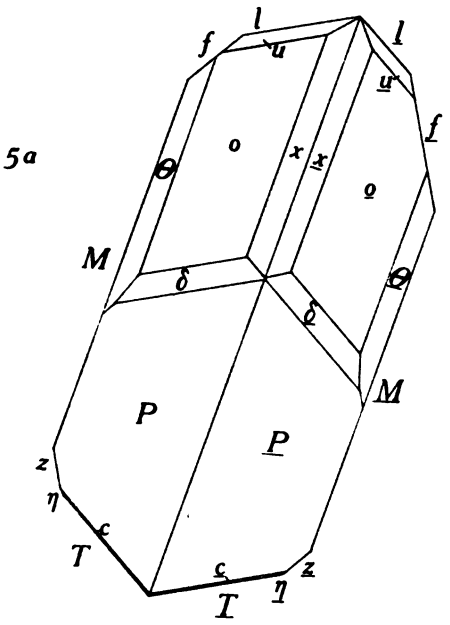

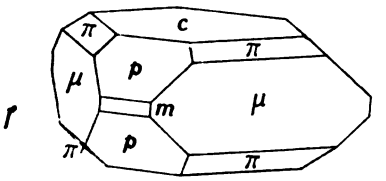

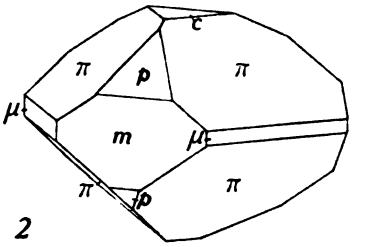

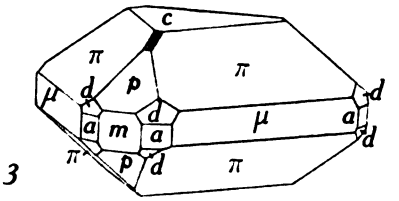

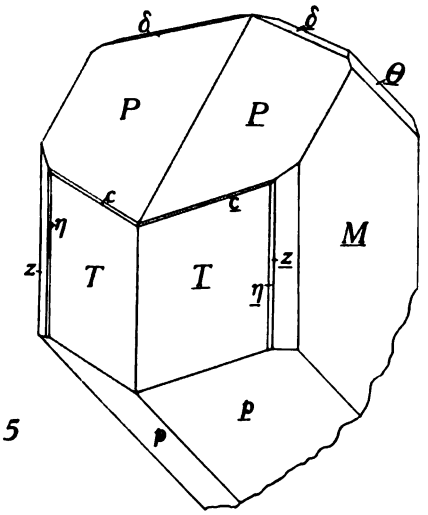

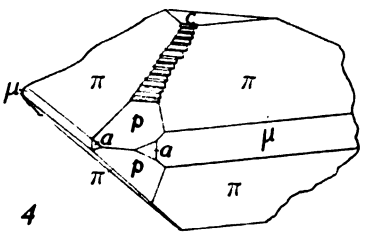

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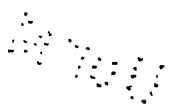

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EXPLANATION OF PLATE 39.

NEPTUNITE.

Forms shown: $c(001)$, $a(100)$, $m(110)$, $s(111)$, $o(\bar{1}11)$, $i(\bar{1}12)$, $g\doteq(\bar{2}11)$, $r(\bar{2}21)$, $p(\bar{3}11)$.

1. Common type. The form g is frequently slightly curved and is of variable width, and p is often the largest of the terminal forms. The back planes almost always cut much lower on the prisms than the front planes.

2. A not very common type with broad development of the unit pyramids, s and o. It shows a common appearance of g with curved edges and narrowing from center toward periphery. It is also very common for the basal plane c to have this outline, elongated obliquely to the symmetry plane, as is also shown in figures 3 and 4.

3. From a doubly terminated crystal with peculiar geometrically asymmetric development. It shows the two most common ways in which r appears, depending on the development of g.

4. Only one crystal of this type of development found. The front pyramid s cuts down lower on the prism than the back pyramid p; i and g are absent, and r and p occur as narrow strips bordering o.

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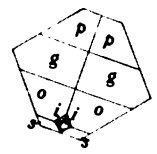

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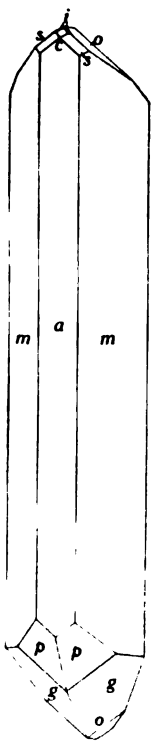

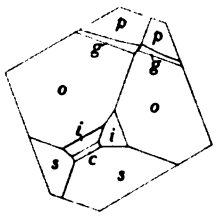

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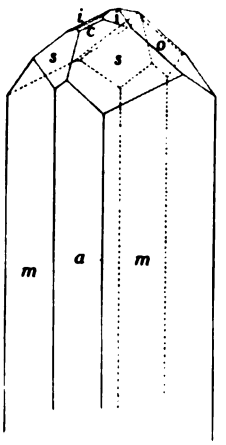

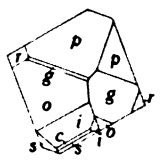

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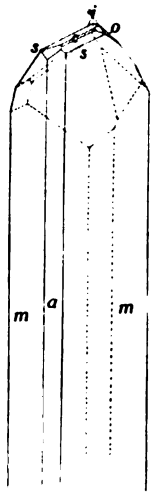

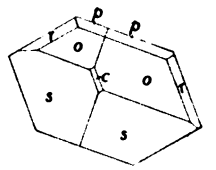

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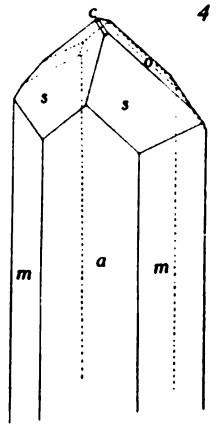

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UNIVERSITY OF CALIFORNIA PUBLICATIONS

BULLETIN OF THE DEPARTMENT OF

GEOLOGY

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THE SKULL AND DENTITION OF A PRIMITIVE ICHTHYOSAURIAN FROM THE MIDDLE TRIASSIC

BY

JOHN C. MERRIAM.

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INTRODUCTION.

The material described in the following paper comprises two specimens which were obtained in the Middle Triassic limestones of West Humboldt Range, Nevada. One of these (no. 9924), showing a portion of the dentition with parts of the lower jaw, was figured and described for inclusion in a recent paper on Triassic Ichthyosauria,[1] but was finally withdrawn, as its systematic position did not seem clearly determined. A second specimen (no. 9853), which has since been exposed for study, shows the middle portion of a skull, with a dentition similar to that of no. 9924.

[1] Merriam, J. C., Triassic Ichthyosauria, Mem. Univ. Calif., vol. 1, no. 1.

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The two specimens available, together with a large number of other Triassic ichthyosaurian forms, were discovered in 1895 by the expedition to West Humboldt Range. The work of this party was made possible through the generosity of Miss Annie M. Alexander, who was herself the discoverer of the type specimen.

Although the relationships of the form represented by these specimens are not entirely clear, it has seemed best to publish such information as is available, in the hope that this material may assist in the interpretation of some of the fragmentary saurian remains obtained elsewhere in Middle Triassic formations. The known material representing some of the older marine Triassic saurians has thus far been very scanty, and the specimens are widely scattered geographically. Only through the publication of illustrations and detailed descriptions of these widely scattered fragments, as they become available, will it be possible to arrive at an understanding of the relationships of the forms which they represent.

DIAGNOSTIC CHARACTERS.

PHALARODON FRAASI,[2] n. gen. and sp.

Plate 40.

Type specimen, no. 9853, Univ. Calif. Col. Vert. Palae., from the Middle Triassic of south fork of American Cañon, West Humboldt Range, Nevada. Cotype, no. 9924, Univ. Calif. Col. Vert. Palae., from the Middle Triassic of Fisher Cañon, West Humboldt Range, Nevada.

Skull of ichthyosaurian type. Orbits moderately large, superior nares situated a short distance anterior to the orbits. Frontals exposed superiorly almost as far forward as the posterior end of the superior narial openings. Nasals apparently not extending far behind the anterior borders of the orbits, and extending forward only a short distance in advance of the superior narial openings. Angular element of mandible not exposed anterior to the middle of the orbit.

[2] φάλαρα, a boss used to adorn head-gear of horses; ὀδούς, a tooth. The species is named in honor of Professor Eberhard Fraas, whose contributions to our knowledge of the Ichthyosauria of Europe have been greatly appreciated by the writer in his comparative studies of this group.

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Dentition differentiated; posterior teeth laterally-compressed, low-crowned; most anterior teeth known relatively small, high-conical, nearly circular in cross-section. Teeth inserted in pits which may be situated at the bottom of a shallow groove. Roots showing coarse longitudinal folds, with little or no cement covering.

DENTITION.

The first specimen to be obtained (no. 9924) consisted of portions of two lower jaws; and a part of the skull, probably representing the maxillary region, containing two nearly parallel rows of teeth quite similar to those of the lower jaws (pl. 40, fig. 2). Very little of the skeletal structure could be determined as the bones were very fragmentary. The elements of the dentition were well preserved.

Fig. 1.—*Phalarodon fraasi.* Inferior dentition. No. 9924, natural size.

The teeth situated on the mandibular elements of specimen 9924 (fig. 1) are of a thick, low-crowned type. They are separated from each other by bony partitions, and appear to be in completely enclosed pits. There is no evidence of the presence of cement surrounding them. Only the thinnest possible cement layer could have been present, as the enclosing bony tissue of the dentary surrounds the roots very closely. The roots are much compressed laterally, and the walls show strong vertical folds. The teeth vary greatly in size and form according to their position in the jaw. The crowns of the most posterior teeth are very low and are considerably compressed laterally. The summits of the crowns are quite abruptly rounded. The most anterior mandibular tooth is hardly more than one-quarter the size of the next to the last one in the series. Its crown is almost round in cross-section, and is more slender

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and more acute than those of the posterior teeth. Several of the middle teeth represented in figure one have been truncated by wear, but the crowns seem to present transition forms ranging between the quite different types at the two ends of the series. In nearly all of the teeth there is a distinctly constricted neck region at the base of the crown.

In the superior dentition, one row of teeth contains only a single complete crown, the most posterior one (pl. 40, fig. 2). The crown of this tooth is gently domed, and is compressed laterally. The bases of several crowns anterior to the complete tooth in this row show a rapid decrease in the size of the teeth anteriorly, with a change in the form of the crowns from a laterally flattened cross-section in the posterior ones to a nearly circular section in the most anterior one. In the other superior row, the few imperfectly represented tooth crowns are of the smaller form with nearly circular cross-section, corresponding to the anterior crowns of the superior series described above.

The dentition of specimen 9853 represents four posterior teeth in the upper, and four in the lower jaws (fig. 2). The most posterior tooth present on the maxillary is situated only a short distance in front of the anterior border of the orbit.

The four teeth on the mandible are of nearly the same size. The crowns are low, laterally-compressed domes, on which the anteroposterior diameter considerably exceeds the height of the crown from the base of the enamel to the summit. The summits of the crowns may show distinct radial furrows. The heavy, laterally-compressed roots show a marked infolded or furrowed structure of the lateral walls. The four teeth are rather closely set in the jaw, but seem to be in pits.

The teeth of the upper jaw are less closely set than those on the dentary, and other teeth may originally have been present in some of the interspaces. The most posterior tooth resembles the two opposing teeth of the lower series. The second tooth from the back of the series is considerably shorter anteroposteriorly than the last, but retains approximately the same transverse diameter. The anterior pair of teeth are still shorter anteroposteriorly. In the most anterior tooth the cross-section shows only a slight lateral compression. The crowns of the

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anterior teeth have approximately the same height as the posterior one, but have the form of simple cones, rather than of laterally compressed domes. In the teeth of both jaws the crowns are swollen just beyond the base, but this feature is par-

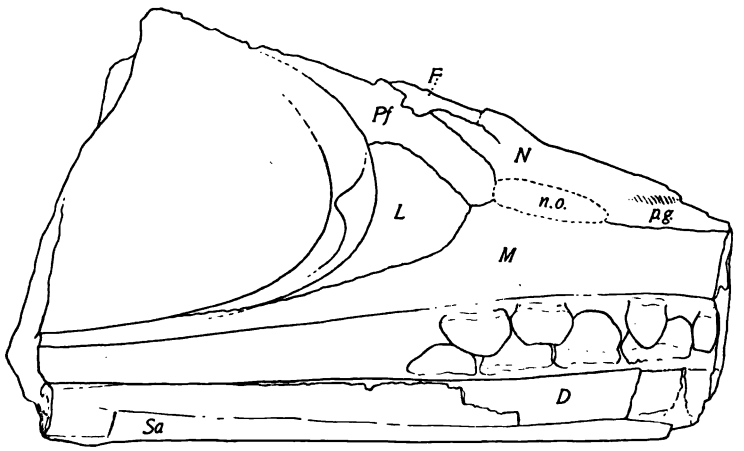

Fig. 2.—*Phalarodon fraasi.* Skull and dentition. No. 9853, natural size. *D*, dentary; *Sa*, surangular; *M*, maxillary; *L*, lachrymal; *Pf*, prefrontal; *F*, frontal; *N*, nasal; *n.o.*, narial opening; *p.g.*, groove for reception of posterior end of premaxillary.

ticularly noticeable in the anterior teeth of the upper jaw, in which the bases of the crowns are much larger than the roots. The enamel of several of the larger teeth shows a tendency to develop radial wrinkles. On the anterior pair of teeth in the upper jaw the enamel is practically smooth. As nearly as can be determined, the anterior upper tooth is set in a shallow pit at the bottom of a shallow, longitudinal groove.

SKULL.

The general form of that portion of the skull preserved in specimen 9853 is in many respects closely similar to that in the Ichthyosauria. Anterior to the middle region of the orbits the head narrows gradually to the most anterior point on this specimen (fig. 3). Judging from the form of the skull as shown here, the rostrum was rather slender and pointed, though it may have been shorter than in the typical ichthyosaurs. The skull

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resembles the ichthyosaurian type in the moderately large orbits and in the position of the superior nares.

The portion of the lower jaw present (fig. 2) shows almost the same vertical diameter for its entire length, and tends to be somewhat narrower vertically below the orbit than in most

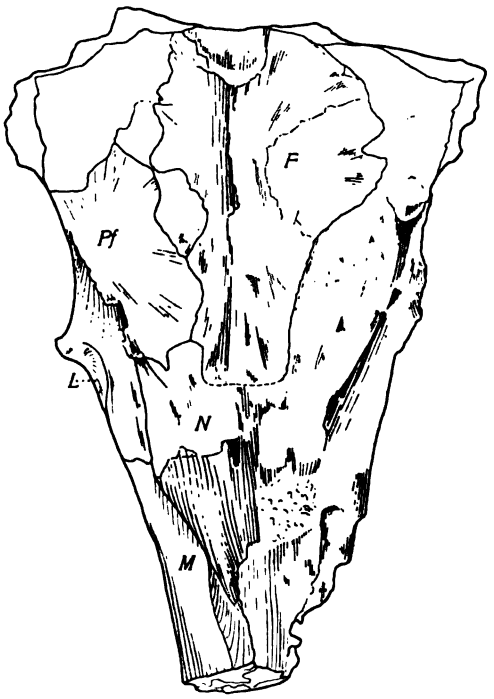

Fig. 3.—*Phalarodon fraasi.* Superior aspect of skull. No. 9853, natural size. *F*, frontal; *Pf*, prefrontal; *L*, lachrymal; *N*, nasal; *M*, maxillary.

of the typical ichthyosaurs. Portions of the dentary, surangular, splenial, and probably the angular elements are represented. A portion of the *dentary* is broken away on each side of the skull, but the posterior end seems originally to have extended back about to the middle of the orbit. The alveolar margin of the dentary is wide, the teeth being set a considerable distance in from the outer margin. The *surangular* extends forward to the anterior end of this specimen, and reaches a point anterior to the superior nares. The heavy *splenials* ex-

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tend the whole length of the skull fragment and reach down to the lower border of the ramus. They are very thin behind the middle of the orbits, but gradually thicken until their diameter immediately anterior to the orbits is several times that opposite the middle of the orbits. The *angular* seems to be represented by a small splint bone situated between the surangular and the splenial just behind the middle of the orbit.

The frontal region is unfortunately only imperfectly preserved, considerable portions of all of the elements represented having disappeared before the specimen was discovered. The *frontals* extend back to a point a little behind the middle of the orbits, where the specimen is broken off posteriorly. The anterior ends of the frontals extend forward almost to the posterior ends of the superior narial openings. Along the superior side of the skull a prominent median ridge is developed at the point of union of the frontals.

The *prefrontals* are large and extend well in toward the median line of the skull. The centers of radiation of the structure lines of the prefrontals are situated a little behind the anterior borders of the orbits. The anterior ends of the prefrontals extend forward to the posterior ends of the narial openings.

The *lachrymals* are large and form the greater part of the anterior borders of the orbits. The lower end of each lachrymal extends back as a slender splint along the maxillary. The limits of the upper posterior border are not distinctly shown, but seem nearly to reach the superior margin of the orbit. The anterior end of the lachrymal extends very near to the posterior end of the superior narial opening. Almost exactly opposite the middle height of the anterior border of the orbit the lateral portion of the lachrymal is extended outward as a prominent, triangular knob.

The *superior narial opening* is evidently represented on one side of the specimen by a very distinct depression occupying almost exactly the same position in the facial region as the narial opening of the ichthyosaurs. The *nasal* elements border the narial openings above, and extend forward to the anterior end of this specimen, where the terminations are exceedingly

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slender, indicating that the anterior end was only a few millimeters in front of this point. The nasal bones extend behind the narial openings for a short distance, but appear not to reach back as far as in other ichthyosaurs.

The form of the nasals and frontals seems in this specimen to be quite different from that in the typical ichthyosaurians. The structure does not, however, correspond to that in the Thalattosauria, as the premaxillaries do not seem to form the principal portion of the bar between the superior narial openings. It is, indeed, not probable that the posterior ends of the premaxillaries reached backward between the narial openings.

The *maxillaries* are formed much as in the ichthyosaurs. The premaxillaries appear to be unrepresented. A rather sharply marked groove extending forward across the lateral border of the nasal from the anterior end of the superior narial opening on one side of the skull was probably occupied by the posterior end of a *premaxillary* having much the same form as in some of the ichthyosaurs.

AFFINITIES.

The skull of *Phalarodon* resembles that in the Ichthyosauria in its general form. It differs from the typical ichthyosaurs in the form of the frontals and nasals, and in the characters of the dentition. The exposed area of the frontals is much larger than in the typical ichthyosaurs, while the nasals seem to be much smaller than in any form thus far described. Not only have the nasals apparently not extended backward over a large part of the frontal region as in *Ichthyosaurus* and *Cymbospondylus,* but their extension anterior to the narial openings is also much shorter. There seems to be good reason for considering that the premaxillaries were separated posteriorly by the nasals as in the ichthyosaurs and proganosaurs. The lower jaw differs from that of most ichthyosaurs in the shortness of the lateral exposure of the angular element, but in this respect resembles the American Upper Triassic genus *Merriamia.* In the Italian *Mixosaurus* the angular also shows a relatively small lateral exposure.

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The dentition most closely resembles that of *Mixosaurus(?) atavus* (Quenstedt) as described by Fraas.[3] The specimens available for examination by Fraas showed unfortunately a very few teeth, but careful observations have indicated that, as in the American *Phalarodon*, the dentition was differentiated; while the roots were coarsely folded, were set in partly or entirely separated alveoli, and possessed little or no cement covering.

The amount of differentiation in the European *M.(?) atavus* is unfortunately not clearly shown. It is, however, noted that the most posterior teeth have low, domed, laterally-compressed crowns, while the crowns of the teeth immediately anterior are more slender and less flattened laterally.

The dental characters of *M.(?) atavus* are so close to those of *Phalarodon* as to suggest very strongly the generic identity of the two. On the other hand the dentition of both forms appears to differ considerably from that of the Italian *Mixosaurus* as described by Repossi.[4] As has been previously suggested by the writer[5] the vertebrae of the *M.(?) atavus* forms seem to differ in some particulars from those of the typical *Mixosaurus*. It appears reasonable to give the *M.(?) atavus* forms a tentative position in the genus *Phalarodon* until further evidence can be obtained regarding the structure of both the American and the European material.

In general skull characters *Phalarodon* seems to represent a member of the Ichthyosauridae more primitive than any form heretofore described. The relatively large exposed area of the frontals, and the relatively small nasals, approach more nearly the form and the relative size of these elements as seen in the early Reptilia generally, than we find them in later ichthyosaurs, or even in the Middle Triassic *Cymbospondylus*. The maxillaries seem also to be comparatively large. It is hardly possible to state definitely whether or not the dentition is primitive, as primitiveness in the sense of closer correspondence to the den-

[3] Fraas, E., Ichthyosaurier der Süddeutschen Trias-und-Jura-Ablagerungen, 1891, S. 38, and Taf. 3, fig. 2 and 3.

[4] Repossi, E., Mixosauro degli strati Triasici di Besano in Lombardia. Atti della Soc. Ital. di Sc. Nat., vol. 41, tav. 8.

[5] Merriam, J. C., Am. Jour. Sc., vol. 19, p. 30, Jan., 1905.

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tition of the ancestor might possibly be expressed in any one of several tooth forms. The general occurrence of a thecodont tooth insertion in early ichthyosaurs suggests that *Phalarodon* is probably not less primitive than the other forms. As to whether the ancestral ichthyosaur possessed a highly differentiated dentition is somewhat doubtful, but the differentiation of the dentition in the European *Mixosaurus,* in *Phalarodon(?) atavus,* and in the American *Phalarodon* suggests that differentiation may be a primitive character. A reëxamination of the dentition of *Cymbospondylus* has not as yet shown any evidence of marked differentiation.

Issued January 21, 1910.

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EXPLANATION OF PLATE 40.

Phalarodon fraasi, n. gen. and sp.

From the Middle Triassic of West Humboldt Range, Nevada.

Fig. 1.—Skull and dentition. No. 9853, natural size.

Fig. 2.—Dentition, with a portion of the mandible. No. 9924, × ⅔.

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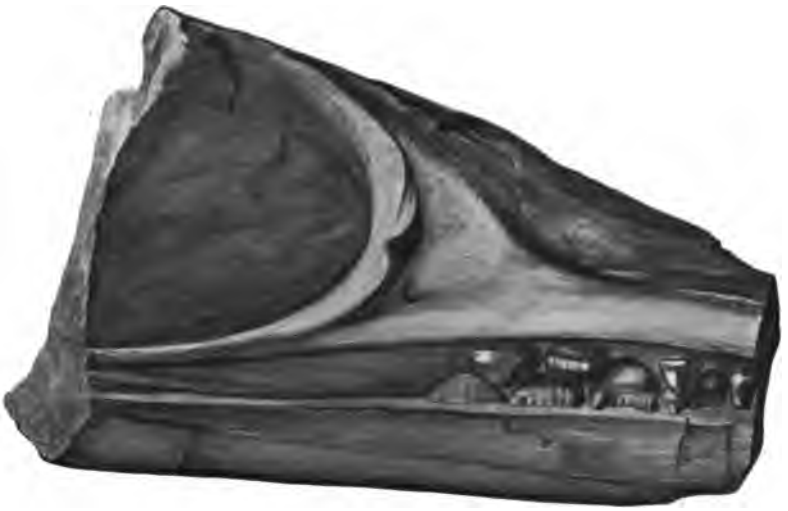

Fig. 1.

Fig. 2.

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BULLETIN OF THE DEPARTMENT OF

GEOLOGY

Vol. 5, No. 25, pp. 391-395 ANDREW C. LAWSON, Editor

NEW MAMMALIA

FROM

RANCHO LA BREA

BY

JOHN C. MERRIAM.

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Canis occidentalis furlongi, n. var. 393
Lynx californicus fischeri, n. var 394

In the collections of mammalian remains from Rancho La Brea there are a number of mammalian species which have not as yet been described. As it is necessary to list a number of these forms in several publications, it is desirable to present the following brief descriptions of the species:

CANIS ORCUTTI, n. sp.

Type specimen no. 10842, Univ. Calif. Col. Vert. Palae., from the asphalt beds of Rancho La Brea near Los Angeles, California.

This species is represented by a considerable number of specimens, amounting to something less than ten per cent. of the total number of skulls representing the Canidae in the Rancho La Brea fauna. The species is closely related to *Canis ochropus* Eschscholtz now living in Southern California. The skulls of *Canis orcutti,* though showing approximately the same length as the living *C. ochropus,* are noticeably broader across the palate and zygomatic arches. The mandible is considerably higher,

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particularly below the molars, and is also thicker transversely than in the living form of this region. The dimensions of the teeth do not vary greatly from the living species except in the thickness of both the upper and lower carnassials, which are much heavier in the fossil form. M^1 tends also to be somewhat heavier and broader on the median side than in the typical *C. ochropus,* and in this respect more nearly approaches the typical *C. latrans.* In M_1 the metaconid seem to be slightly less prominent medially than in the typical *C. ochropus,* possibly owing to the greater thickness of the trigonid blade in the fossil form.

A skeleton of this species which has been assembled from parts of separate individuals seems to show quite distinctly that the animal was a rather slender, long-legged creature and evidently swift footed as the living coyotes.

MEASUREMENTS.

	No. 10842
Length from anterior side of premaxillaries to posterior side of occipital condyles	188.5 mm.
Width across zygomatic arches	108
Width between outer sides of tritocones of P^4	65
Least width between superior borders of orbits	38
Width between postorbital process of frontals	55
Length, posterior side of superior canine to posterior side of M^2	80.5
Length, anterior side of P^4 to posterior side of M^2	37.3
P^3, anteroposterior diameter	13.3
P^4, anteroposterior diameter	21.2
P^4, thickness across protocone	8.5
M^1, anteroposterior diameter measured along outer border	13.3
M^1, greatest transverse diameter	16
M^2, anteroposterior diameter measured along outer border	7.3
M^2, greatest transverse diameter	10.5
	No. 11278
Length, anterior end of left ramus of mandible to middle of posterior side of condyles	145.5 mm.
Height of mandible below posterior side of P_2	17
Height of mandible below posterior side of M_1	22.5
Thickness of mandible below protoconid of M_1	11.8
Length, posterior side inferior canine to posterior side M_2	85
P_3, anteroposterior diameter	11.7
P_3, greatest transverse diameter	4.8
M_1, anteroposterior diameter	22.9
M_1, greatest transverse diameter of trigonid portion	9.5
M_2, anteroposterior diameter	9.8

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CANIS ANDERSONI, n. sp.

Type specimen no. 12249, Univ. Calif. Col. Vert. Palae., from the asphalt beds of Rancho La Brea near Los Angeles, California.

This species is represented by a young adult skull of a small wolf with a much smaller and also relatively broader skull than *C. orcutti.* Though this specimen represents a young individual it differs so much in form from all the other known species in this region that it seems necessary to refer it to a distinct specific group.

MEASUREMENTS.

	No. 12249
Length from anterior side of premaxillaries to posterior side of occipital condyles	166.1 mm.
Width across zygomatic arches	91
Width between outer sides of tritocones of P^4	56
Least width between superior borders of orbits	31.9
Width between postorbital process of frontals	38.2
Length, posterior side of superior canine to posterior side of M^2	*a*, 64.5
Length, anterior side of P^4 to posterior side of M^2	*a*, 36.5
P^4, anteroposterior diameter	20
P^4, thickness across protocone	7.8

a, approximate.

CANIS OCCIDENTALIS FURLONGI, n. var.

Type specimen no. 11283, Univ. Calif. Col. Vert. Palae., from the asphalt beds of Rancho La Brea near Los Angeles, California.

There are in the Rancho La Brea collections several fragmentary specimens representing a wolf considerably smaller than the smallest individuals of *Canis indianensis* type, and evidently representing a form closely related to the existing North American timber wolves. In the details of structure the teeth are, however, distinguishable from those of the living forms.

In the type specimen, which is a right maxillary with the molars and carnassial, the anterior region of the palate seems relatively narrow, though perhaps not narrower than in the existing species.

The superior carnassial is massive and the deuterocone seems to have been small. On M^1 the hypocone is much larger than in *C. indianensis* and has approximately the same size as in *C. pambasileus.* The anterior end of the hypocone cusp is extended around the anterior side of the protocone as a faint ridge, instead of being interrupted on the antero-internal portion of the

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tooth as in *C. indianensis.* M^2 is rather narrow anteroposteriorly; the metacone is small and the hypocone seems also to be relatively small.

In a fragment of a lower jaw accompanying specimen 11283 the carnassial possesses an exceedingly weak metaconid, while the entoconid is slightly larger than in the average specimen of *C. indianensis.* The metaconid is even weaker than in *C. indianensis* and approaches the relative size seen in a specimen of *C. pambasileus* available. On M_2 the protoconid seems slightly smaller and the heel portion relatively larger than in *C. indianensis,* though the metaconid is relatively small compared with the hypoconid. The proportions of the talonid region with reference to the trigonid portion of the tooth are much as in the Recent wolves.

In another specimen (no. 10733), of nearly the same dimensions, from this locality the hypocone of M^1 is smaller than in specimen 11283, though larger than in the typical *C. indianensis.* The anterior extension of the hypocone ridge around the anterior side of the protocone is also interrupted as in *C. indianensis.* M^2 is in this specimen of the narrow form with small metacone and hypocone as in no. 11283. P^3 differs from the corresponding tooth of *C. indianensis* in being very narrow instead of wide posteriorly, and in the almost entire absence of a posterior basal tubercle behind the posterior cusp. The portion of the palatine region represented suggests narrowing anteriorly. This specimen almost bridges the gap between the *C. occidentalis* and the *C. indianensis* types but is nearest to *C. occidentalis furlongi.*

MEASUREMENTS.

	No. 11283	No. 10733
Length, posterior side of superior canine to posterior side M^2	81.5 mm.	
Length, anterior side P^4 to posterior side M^2	44.7	
P^4, anteroposterior diameter	23.6	24 mm.
M^1, anteroposterior diameter along outer border	16	15.5
M^1, greatest transverse diameter	19.3	18
M^2, anteroposterior diameter along outer border	8	8.2
M^2, greatest transverse diameter	10.8	10.5
Width, from outer side of alveolus of M^1 to median line	39	37.7
Width, from outer side of alveolus of P^1 to median line	18	
M_1, anteroposterior diameter	27	
M_1, thickness measured across protoconid	11.5	
M_2, anteroposterior diameter	11	

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LYNX CALIFORNICUS FISCHERI, n. var.

Type specimen no. 11287, Univ. Calif. Col. Vert. Palae., from the asphalt beds of Rancho La Brea near Los Angeles, California.

Two small cats of the *Felis* type are represented in the asphalt fauna by lower jaws. One specimen closely resembles in all of its characters *Lynx californicus* found at the present time in Southern California. In another form which is made the type of the new variety, *fischeri,* the jaw has about the same length as in the living species but is much more slender and the carnassial is somewhat larger. As yet no complete skeleton material of this form has been obtained.

MEASUREMENTS.

	No. 11287
Length, posterior side of canine alveolus to posterior side of M_1	33.9 mm.
M_1, anteroposterior diameter	11.2
Height of mandible below protoconid of M_1	12.2
Thickness of mandible below protoconid of M_1	7.5

Issued January 31, 1910.

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BULLETIN OF THE DEPARTMENT OF

GEOLOGY

Vol. 5, No. 26, pp. 397-403 ANDREW C. LAWSON, Editor

AN APLODONT RODENT FROM THE TERTIARY OF NEVADA.

BY

EUSTACE L. FURLONG.

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INTRODUCTION.

In June, 1906, Professor John C. Merriam of the University of California visited the region of Virgin Valley in northwestern Nevada, and obtained a small collection of mammalian remains representing the fauna of an extensive Tertiary formation exposed in that locality. This fauna was considered by Professor Merriam[1] to represent the Miocene. The upper division was presumed to correspond to a stage of the Miocene not older than the Mascall beds of the John Day region. The fauna of the lower horizon was considered as Miocene, though the particular stage was not determined.

[1] Science, N. S., vol. 26, p. 380. 1906.

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During the past summer a continuation of the work begun in 1906 was carried on by a party from the University of California, organized and supported financially by Miss Annie M. Alexander. The field party spent the greater portion of the summer in Virgin Valley and the adjoining regions, and obtained a considerable collection of material representing the fauna of these beds. Among the mammalian specimens obtained, one of the most interesting series represents the peculiar group of aplodont rodents, which has previously been known fossil only by the specimens obtained in the Quaternary fauna of Potter Creek Cave and Hawver Cave. This group, represented by the living *Aplodontia,* has occupied an isolated position among the Rodentia and comparatively little has been known of its affinities. Valuable suggestions as to its relationships have been made by various authors, particularly in recent papers by Sinclair,[2] and by Matthew and Gidley.[3] As is shown in the following article, forms very closely allied to the modern genus *Aplodontia* occur in the Virgin Valley region in association with a fauna containing such forms as *Mylagulus, Dipoides, Hypohippus, Merychippus, Palaeomeryx,* and *Chalicotherium,* with various other types which represent a late Tertiary fauna.

DIAGNOSTIC CHARACTERS.

APLODONTIA ALEXANDRAE, n. sp.

Type specimen, no. 11325, Univ. Calif. Col. Vert. Palae. Maxillaries with slightly worn teeth. Cotypes, no. 11898, Univ. Calif. Col. Vert. Palae. Maxillaries with nearly complete dentition; no. 11899, left P^4, unworn tooth; no. 11897, right ramus of mandible with complete dentition with exception of incisor; no. 11909, right ramus of mandible with complete dentition. Locality, late Tertiary beds, Virgin Valley and Thousand Creek, Northwestern Nevada.

Larger than *Meniscomys hippodus* Cope, Middle John Day, Oregon. Smaller than the Recent *Aplodontia rufa* Merriam

[2] Am. Jour. Sc., vol. 15, p. 143. 1903.

[3] Amer. Mus. Nat. Hist., vol. 20, p. 206. 1904.

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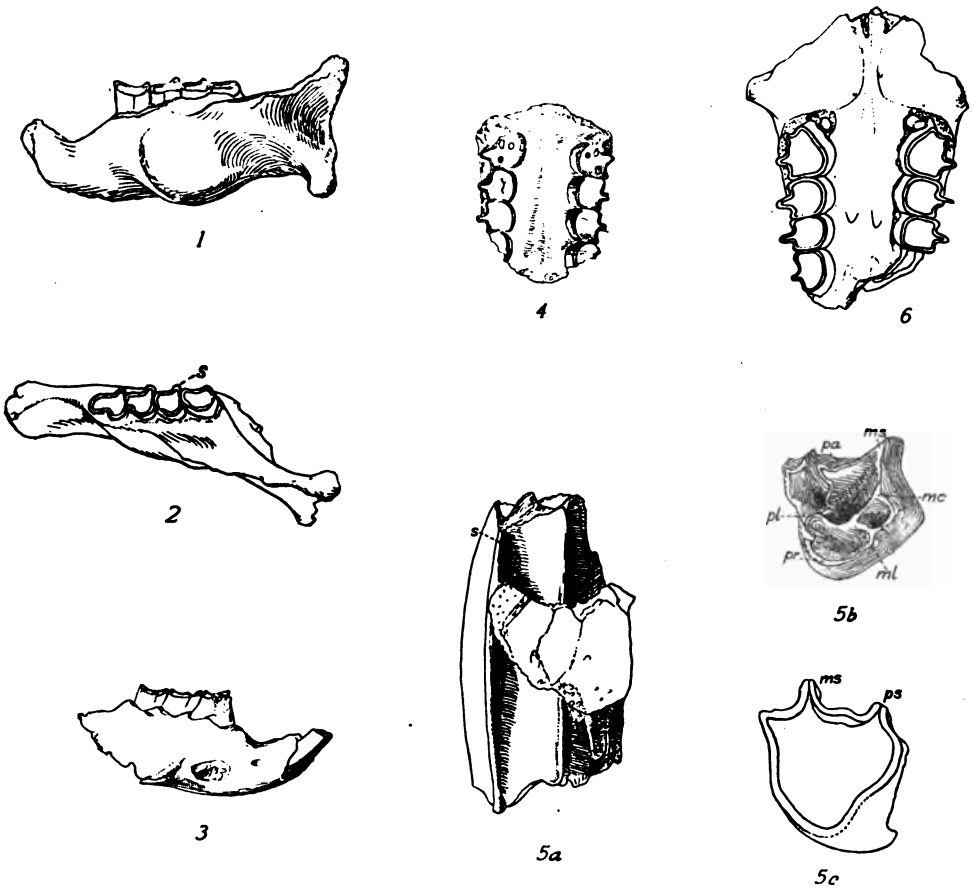

Figs 1 to 5*c*.—*Aplodontia alexandrae*, from late Tertiary beds of Virgin Valley and Thousand Creek, Northwestern Nevada.

Figs. 1 and 2.—Left ramus of mandible. No. 11897, × 1½. Fig. 1 lateral view. Fig. 2 occlusal view; *s*, posterior median style.

Fig. 3.—Right ramus of mandible lateral view. No. 11909, × 1½.

Fig. 4.—Superior dental series. No. 11325, × 1½.

Figs. 5*a* to 5*c*.—P^4. No. 11899, × 6. Fig. 5*a*, lateral or external view; *s*, metastyle; Fig. 5*b*, occlusal view; *pr.*, protocone; *pl.*, protoconule; *pa.*, paracone; *mc.*, metacone; *ml.*, metaconule; *ms.*, mesostyle. 5*c*, cross-section of superior end; *ms.*, mesostyle; *ps.*, parastyle.

Fig. 6.—Superior dental series. No. 11898, × 2.

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C. H. Superior dental formula ^{1}, ^{0}, ^{2}, ^{3}. P^3 a small, well-developed cylindrical tooth as in *Aplodontia rufa*. P^4 with strongly developed parastyle, mesostyle and metastyle, the latter more distinct than in the Recent *Aplodontia*. The three upper molars with well-developed styles.

Median style absent in the lower molars and in P_4. The enamel of the inner wall in the inferior teeth extends back in an unbroken surface to a prominent style on the posterior side of the inner wall.

The unworn P^4 of *A. alexandrae* differs from that of *A. rufa* in the presence of a longitudinal median ridge separating the median part of the tooth transversely into two lakes. In *A. rufa* the median lake extends from the ectoloph to the inner wall of the tooth.

SUPERIOR DENTITION.

The upper teeth are well represented in no. 11325 (fig. 4); no. 11898 (fig. 6); and in no. 11899 (figs. 5*a*, 5*b*, 5*c*), an unworn premolar four. These specimens show different stages of wear. In no. 11325, P^4, a worn tooth, shows the protocone, metacone, and paracone to occupy approximately the same position as in a specimen of *Aplodontia*, figured by Matthew and Gidley.[4] The molar teeth closely resemble those of *Aplodontia*.

In no. 11898 (fig. 6) the tooth series lacks left M^3 and right P^3. The teeth are more worn than in no. 11325 with a pattern much as in *Aplodontia rufa*. The small P^3 is excellently preserved in the left maxillary. P^3 of the right is broken at the alveolus, showing the root of the tooth in place. The frontals are completely broken away with the superior ends of the tooth series exposed. The roots are fully open and show the typically hypsodont character. The mesostyle extends to the tip of the root as seen in Recent specimens of *Aplodontia* and in the Quaternary forms from Potter Creek Cave.

In no. 11899 (figs. 5*a*, 5*b*, 5*c*), an unworn fourth premolar, there are four deep lakes, an anterior, a median, a posterior, and

[4] Op. cit.

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an inner. The metaconule and protoconule unite to form a high longitudinal ridge, the anterior end of which joins with the protocone to form the boundary walls of the inner lake. The ectoloph is produced externally in a prominent mesostyle. The metacone and paracone give rise to transverse ridges that join the metaconule and paraconule respectively on the median ridge. The paracone ridge separates the anterior lake from the median lake and the metacone ridge separates the posterior lake from the median one.

A left fourth premolar of no. 11325 (fig. 4) shows advanced wear. The large lakes in no. 11899 are represented in no. 11325 by small lakes, two placed anteriorly and one posteriorly on the crown. The fourth premolar in no. 11898 (fig. 6) shows further wear, the cuspules are completely worn away and the worn crown closely resembles that in the Recent *Aplodontia.*

INFERIOR DENTITION.

Inferior dental formula $_{1,\ 0,\ 1,\ 3}$. In *Aplodontia rufa* (no. 3748, Univ. Calif. Mus. Vert. Zool.) the inner side of the teeth a little anterior to the middle portion is produced into a prominent style that is constant throughout the depth of the teeth. This character is also present in *Aplodontia* from Potter Creek Cave.

In a mandible of *Meniscomys hippodus* (no. 606, Univ. Calif. Col. Vert. Palae.) and other specimens in the University collection the teeth have prominent median styles. The teeth of *Meniscomys* also show a decided tendency to hypsodonty. The style is confined to the upper portion of the teeth, not extending below the alveolar border.

In *Aplodontia alexandrae* nos. 11897 (figs. 1 and 2), 11909 (fig. 3), and others, the inner walls of the teeth are produced posteriorly in a gently concave unbroken surface to a prominent style on the posterior region of the inner margin of the teeth.

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MEASUREMENTS.

	A. rufa No. 3748*	No. 11325	*A. alexandrae* No. 11898	No. 11899
Length from anterior side P^3 to posterior margin M^3	18.5 mm.	18.5	12.5	
P^4, anteroposterior diameter	5.	4.5	3.5	3.5
P^4, greatest transverse diameter	5.	4.	4.	4.
M^1, anteroposterior diameter	4.	2.5	2.5	
M^1, greatest transverse diameter	4.5	3.	4.	
M^2 anteroposterior diameter	4.	2.5	2.5	
M^2, greatest transverse diameter	4.5	3.	3.	
M^3, anteroposterior diameter	4.5	3.	3.	
M^3, greatest transverse diameter	4.		2.5	
Length from anterior palatine foramen to P^3	11.		7.5	
Length from anterior palatine foramen to posterior margin M^3	29.		19.	
Greatest width between anterior external borders of alveoli of P^4	16.5	12.	12.	
Width of palate on plane of alveoli between P^3 and anterior palatine foramen	5.		1.	
Width of palate between inner borders of P^4	6.	4.5		
Width of palate between inner borders of M^3	6.	4.5		

	A. rufa No. 3748*	*A. alexandrae* No. 11897	No. 11909
Total length of inferior cheek tooth series	17. mm.	11.	12.
P_4, anteroposterior diameter	5.	3.5	4.
P_4, transverse diameter	4.	2.5	2.5
M_1, anteroposterior diameter	4.	2.5	2.5
M_1, transverse diameter	3.5	3.	3.
M_2, anteroposterior diameter	4.	2.5	2.5
M_2, transverse diameter	3.5	3.	2.5
M_3, anteroposterior diameter	4.5	3.	2.5
M_3, transverse diameter	3.	2.	2.
Height of mandible at P_4	14.	9.5	9.
Length of mandible from condyle to posterior margin of incisor alveoli	45.	31.	

* Number from Univ. Calif. Mus. Vert. Zool.

MAXILLARIES.

In a *Meniscomys* specimen (no. 1100) the maxillaries meet in a nearly horizontal plane on the palatal surface.

The maxillaries in *A. alexandrae* (no. 11898) are keeled medially, anterior to P^3 and back of the anterior palatine foramina

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and in the median line only. From a slight depression anterior to the dental series, they extend laterally on a nearly horizontal plane to the infraorbital foramina. The Recent species differ in this respect in that the maxillaries slope upward more sharply from the median line.

GENERIC POSITIONS AND AFFINITIES.

A. alexandrae represents an advanced stage of development between *Meniscomys* and *Aplodontia*. It shows a distinct likeness to both genera, and is probably near the direct line of descent leading toward *Aplodontia*. The genus *Mylagaulodon* Sinclair shows affinity to *A. alexandrae* through *Meniscomys*. It is probably an aberrant form of the Aplodontidae as was recently suggested by Matthew and Gidley.[5]

[5] Op. cit.

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BULLETIN OF THE DEPARTMENT OF

GEOLOGY

Vol. 5, No. 27, pp. 405–411, pls. 41–42 ANDREW C. LAWSON, Editor

EVESTHES JORDANI

A PRIMITIVE FLOUNDER

FROM THE

MIOCENE OF CALIFORNIA

BY

JAMES ZACCHAEUS GILBERT.

INTRODUCTION.

The specimen of fossil flounder here described as new was obtained from the diatomaceous beds near Lompoc now being commercially worked by the Magna Silica Company, of Los Angeles, California; and it was through the courtesy of George B. Hanniman of that company that this specimen was obtained. In these beds have been found several specimens of fishes, but the most perfect is this one. This specimen is an imprint of apparently a mature fish almost complete and very well defined.

Preliminary notes with a plate were published in January, 1909,[1] but no name has hitherto been assigned.

This species differs from all other flounders in the greater development of the body-cavity, and from most of them in the very large size of the mouth. The generic name *Evesthes* is given because this flounder was a large-mouthed one and doubtless a voracious eater; and the specific name is proposed in honor of Dr. David Starr Jordan, to whom I am much indebted for his unstinted encouragement and valuable aid in the preparation

[1] Bull. So. Cal. Acad. Sci., vol. 8, p. 24, pl. 2.

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of this paper. The principal fossil flounders have been obtained from the Eocene and Miocene beds of Europe and nearly all of them have been referred to the genus *Rhombus*, of which *Bothus* is an older name. *Bothus minimus* is the oldest known species, having been described by Agassiz from the Eocene of Monte Bolca. The other nominal species, mostly Miocene and known from fragments only, are closely related to this. The fact that these fragments belong to the general type of the turbot and brill (Psettinae) has led to the supposition that this was the primitive type of the flat-fishes. The halibut tribe Hippoglossinae are less specialized, but as Jordan and Evermann observe, "The primitive simplicity of the halibuts may be due to degeneration." To this date no Hippoglossinae have been found fossil, nor have any of the small-mouth forms (Platessinae) which are supposed to be derived from the Hippoglossinae, except in very recent rocks.

It is believed that the specimen described here may be found to be of great significance in this matter, as it is apparently a primitive representative of the halibut tribe, being more generalized than *Bothus minimus*, as well as vastly larger in size than that diminutive species.

The identification of the flounders will doubtless rest largely upon skeletal differences such as: the degree of approach to symmetry; the insertion of the ventral fin; the simplicity, number, and strength of the vertebrae; the relative size of the head and body-cavity; the position of the eyes; the strength of the bones; the number and relation of the spines to the interspinous bones; the character of the fins and the number of their rays; the presence and character of the teeth and the length and direction of jaws, etc. In considering these points several problems suggest themselves, among which are (*a*) whether the earlier flounders had a large or small mouth; (*b*) whether they had large teeth or small; (*c*) whether they were "right" or "left-handed" forms; (*d*) whether they resembled the halibuts more than they did the brill or the turbot; (*e*) what was their habitat; (*f*) and what kind of a form should be looked for as the common ancestor of both soles and flounders, for two species of sole are also found in the Miocene of Europe.

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EVESTHES JORDANI, n. gen. and sp.

From the Miocene of Lompoc, Santa Barbara County, California.

This specimen is characterized as follows: head large with strong bones, and occupying more than one-third of the total length of the body exclusive of the caudal fin; eyes on the right side; mouth large, with strong sharp conical teeth; a great body-cavity extending backward to more than the one-half of the entire length of the fish and occupying two-thirds of the total depth; strongly dorsalward position of the spinal column; vertebrae few, 33, with poorly developed ventrolateral processes and spines; general weakness of the body skeleton; uniform arrangement of two interspinous bones to one ray; weakness of the bones forming the posterior boundary of the body-cavity; solid and unsymmetrical hypural bone; and the small angle of 44 degrees made between the direction of the premaxillaries and that of the spinal column.

The *pectoral fin* lies with the middle of its base 40 mm. below the middle of the spinal column and 47 mm. above and 10 mm. behind the ventral fin. The posterior border of the operculum reaches its base and eleven rays are discernible. The fin is weak and the rays are only 22 mm. long. The ventral fin is imperfect, but reveals three strong rays 10 mm. in length. Four branchiostegals occur, but are incomplete.

The *dorsal fin* begins apparently above the middle of the left orbit and extends to the 29th vertebra, that is, to within 4 vertebrae of the hypural. About 64 rays are present, and they are comparatively slender, weak and strongly recurved. A few rays are wanting, but those present indicate a uniformity of one ray to each interspinous bone, with two of the latter uniting with each neural spine.

The *anal fin* is incomplete anteriorly, but the part present indicates that it was a half higher than the dorsal and much stouter.

The *rays* were about 42 in all, 30 of which were attached through their interspinous bones in twos to the haemal spines. The longest rays and interspinous bones are attached to the first three caudal vertebrae as is the case with the dorsal fin, and the length of the interspinous bones is equal to that of the corresponding haemal spines. The arrangement of the two interspinous bones to each haemal and neural spine is very uniform throughout, which is not the case in some of the living halibuts and flounders. For instance, in *Psettichthys melanostictus* the neural spines of the 14th, 18th, and 23rd vertebrae attach each three interspinous bones instead of two as in the fossil; also in *Platichthys stellatus* the neural spines of 1st, 4th, 9th, 11th, 15th, 18th, 21st, and 24th vertebrae each receives only one

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bone. In *Paralichthys californicus* the neural spine of the 16th vertebra and the haemal of the 15th attaches each only one, otherwise regularly two. That this point is of value must be shown by further observation than I have been able to make.

The *caudal fin* is broadly spread (margin 75 mm.) and the fin-rays are in length about two-thirds the spread. The hypural is solid, not vertebra-like, without a neck-like portion, and receives support from the spines of the last vertebra only. The rays, seventeen in number, are very strong at the base, weaken rapidly backward, are branched distally, and the first lateral pair are 15 mm. long, outwardly curved and stout. The next one on either side, 24 mm. long, is weaker and not branched. The hypural is unsymmetrical, the dorsal margin being only two-thirds the length of the ventral.

The *vertebrae,* 33 in number, retain their strength well from the sixth backward. The first five are very much smaller than the succeeding ones and curve strongly ventralward as they approach the skull. All are very much weaker than those of the robust *Platichthys stellatus* but very strikingly resemble the smaller deep-sea flounders of our coast, as well as the large "bastard halibut," *Paralichthys californicus.* The ventrolateral processes are very weak, being less in length than the width of the corresponding vertebrae. The 3rd to the 12th bear very slender weak ribs, the longest being 36 mm. The spines of the caudal vertebrae decrease gradually in length to the 28th, whence backward they slightly increase.

The bones of the *head* are very strong, the premaxillaries, maxillaries, and mandibles standing out prominently and well defined. Both eyes occur upon the right side, as in the halibut; the left orbit lies farther back than the right, and its upper margin reaches to within 2 mm. of the dorsal margin of the skull. The interorbital space is one-half the width of the right orbit and an irregularly V-shaped suture occurs between the orbits.

The maxillaries are long and slender, but strengthen quite strongly backward, and are arched 5 mm., the more strongly so anteriorly. Their general direction makes an angle of 44 degrees with that of the spinal column. The dorsal process anteriorly stands at an angle of 90 degrees with the axis of the premaxillaries here. Three large conical-shaped teeth, slanting slightly backward, occur in the premaxillaries in front, the third being the strongest and longest. Back of these for the entire biting surface occur sharply conical, closely set teeth (6 to the cm.) in a single row and decreasing backward. The mandibles strengthen rapidly backward where the depth is one-fifth the length. They probably bore even, sharp, broadly conical, and slightly slanting teeth. Five can be made out quite definitely and a space for two occurs between the first three and the last two. The dental surface is slightly arched, the ventral surface of the maxillaries is not shown, but the lateral view shows them long and strong, parallel with the premaxillaries. The very long jaws, the sharp, large teeth, and the open mouth present a very ferocious aspect. In the direction of the maxillaries, the size of the mouth, and in the character and strength of the teeth this form differs radically from the living allies of the genus *Bothus.* Some of the Hippoglossinae as the "bastard halibuts" approach these characters. No trace of scales is present.

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From the above facts of description and the following measurements it seems fairly assured that this fish, on account of its strongly compressed body, broadly diamond-shaped outline, unsymmetrical head, twisted skull, both eyes on the same side, and strong teeth, is a flounder, and belongs to the Pleuronectidae. It is apparently ancestral to the present sub-families of Hippoglossinae, finding its nearest allies among living genera in *Paralichthys, Velifracta* (*Tephritis*) and other tropical forms of the Hippoglossinae, the group *dd* of Jordan & Evermann (Fishes N. M. America 111, p. 2606), which contains the allies of *Paralichthys* and *Pseudorhombus*. These allies of *Paralichthys* are all normally sinistral, but in several of the Pacific species, *Paralichthys californicus,* with the allied genera, *Xystreurys, Hippoglossina, Velifracta, Verasper,* and *Psettodes,* the eyes are as often on the right side as on the left. In the true Hippoglossinae, the eyes are always on the right side. In the Psettinae they are always on the left.

If this specimen had the eyes on the right side, as I believe is the case, it cannot be allied to *Bothus*, nor can it belong to the Psettinae. On the other hand, its small number of vertebrae separates it widely from the Hippoglossinae proper. We are therefore forced to range it with the occasionally dextral allies of *Paralichthys,* and to these, in general, its skeleton shows greatest resemblance.

The small number of fin-rays seen in *Evesthes* (D. 64, A. 42) is approached by the California species *Hippoglossina stomata* (D. 68, A. 53) and by the bastard halibut of California (D. 70, A. 55). In *Velifracta sinensis* the number is still further reduced (D. 46, A. 35). In *Psettodes erumei* we have D. 50, A. 40. The nearest living ally of *Evesthes* is probably *Hippoglossina,* with which it seems to agree in the insertion of its dorsal, and *Paralichthys.* The small number of vertebrae in *Evesthes* shows that the species was an inhabitant of warm seas, and doubtless a shore fish. The number of vertebrae (33) corresponds nearly to that found in *Bothus minimus* (31) and to the number (31) in *Pleuronectes* (*Psetta*) *maximus.* In the true halibut (*Hippoglossus*) there are 50, and in the brill (*Bothus rhombus*) there are 36. The minute *Bothus minimus* probably

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does not belong to the genus *Bothus* as now defined, but its relations with that genus must be close. *Evesthes* seems more primitive than *Bothus*. In *Paralichthys californicus* there are but 35 vertebrae, and this number is probably general in *Hippoglossina, Xystreurys, Pseudorhombus,* and other allies. The Atlantic species of *Paralichthys* have in general more vertebrae (37 to 40), and more fin-rays.

None of these genera has so large a body-cavity as *Evesthes, Paralichthys* approaching most nearly. *Psettodes,* an Asiatic genus, also indifferently dextral and sinistral, also approaches *Evesthes,* but in this genus the dorsal fin begins at the nape.

Evesthes jordani stands unique in its very large head and strong jaws; strong teeth; direct mouth; large body-cavity; in the small number of the vertebrae, the first five of which are greatly reduced and ventrally curved (a feature of the codfish), the strength of the succeeding ones carried well backward; and in the relatively small number of fin-rays.

While the discovery of this species may not preclude the possibility that the sinistral, large-mouthed flounders of the turbot tribe are the most primitive, yet it seems to me that the dextral forms with a large head, large body-cavity, and a very large mouth, will be found most primitive of all. *Evesthes* is certainly a more primitive type than *Bothus* or *Paralichthys.*

The group of turbots should rather be called Pleuronectinae than Psettinae. Dr. Jordan calls my attention, in his valuable editorial reading of this article, to the fact that in the first restriction of the genus *Pleuronectes,* that of Fleming (1828), the name was restricted to the turbot (*Pleuronectes maximus*). The name *Pleuronectes* therefore, under the rules of the International Zoological Congress, should replace *Psetta;* and Pleuronectinae would supersede Psettinae.

MEASUREMENTS.

Length, anterior end of premaxillary to base of hypural	268	mm.
Length, anterior end of premaxillary to first caudal vertebra (13th)	148	
Length, total, including caudal fin	338	
Length, anterior end of premaxillary over dorsal curve to base of caudal fin	300	

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Length of ventral curvature, anterior end of premaxillary, to base of caudal fin	327	mm.
Depth from base of dorsal to base of ventral fin at 11th vertebra (in length 2)	131	
Depth here to middle of spinal column (in depth 3 times)	47	
Depth at same place of body-cavity (in length 3 times)	84	
Depth at ventral fin (in length of head to gill opening 1)	117	
Length of head to dorsal fin (in length of dorsal curve 6)	50	
Length of head to first vertebra	79	
Length of head to posterior margin of operculum	117	
Length of head (in greatest length 2)	165	
Distance to base of ventral fin	112	
Depth from middle of first vertebra to branchiostegals (in length 1)	80	
Depth of head at posterior margin of orbits	80	
Height of dorsal fin-rays, 11th vertebra	18	
Height of anal fin-rays, 11th vertebra (in depth of body 5)	26	
Length of caudal fin-rays	52	
Length of hypural bone, upper margin 17 mm., lower margin	25	
Length of hypural, middle line 22 mm., posterior margin	32	
Length of anal fin-rays	27	
Length of haemal interspinous bones (in rays 5, in spines 1)	45	
Overlap of interspinous bones with haemal spines	12	
Length of neural spines 27 mm., at 13th vertebra; haemal at 13th	45	
Length of vertebrae, 1st to 5th, average, 4 mm.; 6th to 12th, 7 mm.		
Length of vertebrae, 13th backward	4.8	
Length of large teeth, 1st, 2 mm.; 2nd, 3.5 mm.; 3rd, 6 mm.; at base 2 mm.		
Length of teeth, in mandibles 2.5 mm.; breadth of base 1.5 mm.		
Length of teeth in premaxillaries 2 mm. to 1 mm., with 6 teeth to cm.		
Length of orbits, left, 32 mm., right (into head 2.5 times) 35 mm.		
Width of orbit, left, 9 mm. (into length 3.5 times).		
Width of interorbital space at suture	6	
Length of premaxillaries (in depth of head posteriorly 1)	63	
Width of premaxillaries posteriorly	12	
Length of mandibles to angle with premaxillaries	59	
Depth of curve of posterior margin of body-cavity	10	
Space between gill opening and posterior margin of body-cavity	47	

The type-specimen (no. 2460) of *Evesthes jordani* has been placed temporarily in the Science and Arts Museum at the Los Angeles High School, Los Angeles, California.

Issued May 21, 1910.

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EXPLANATION OF PLATE 41.

Evesthes jordani, n. gen. and sp. Impression of the right side of the skeleton, reproduced one-half natural size.

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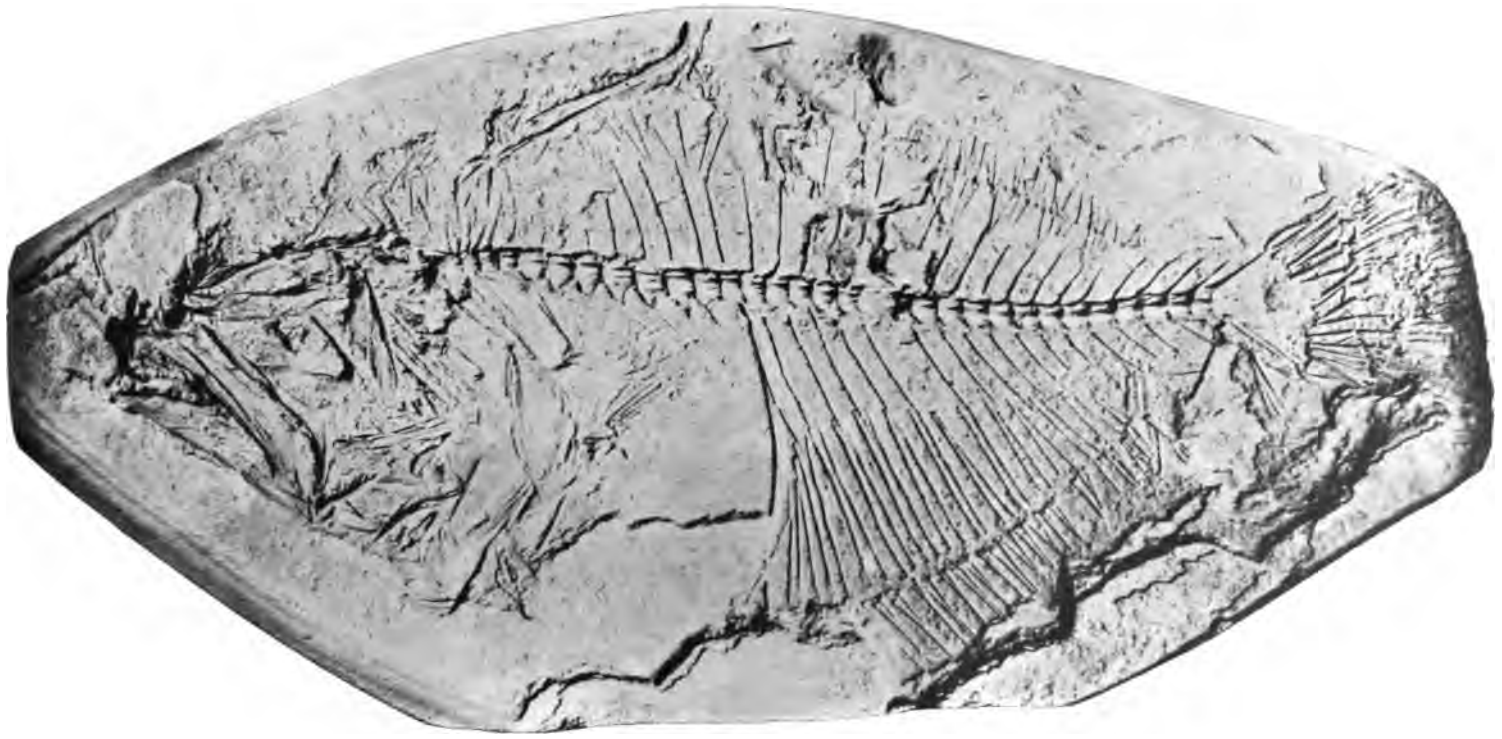

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EXPLANATION OF PLATE 42.

Evesthes jordani, n. gen. and sp. Restoration, one-half natural size. Drawn by author, redrawn by William S. Atkinson.

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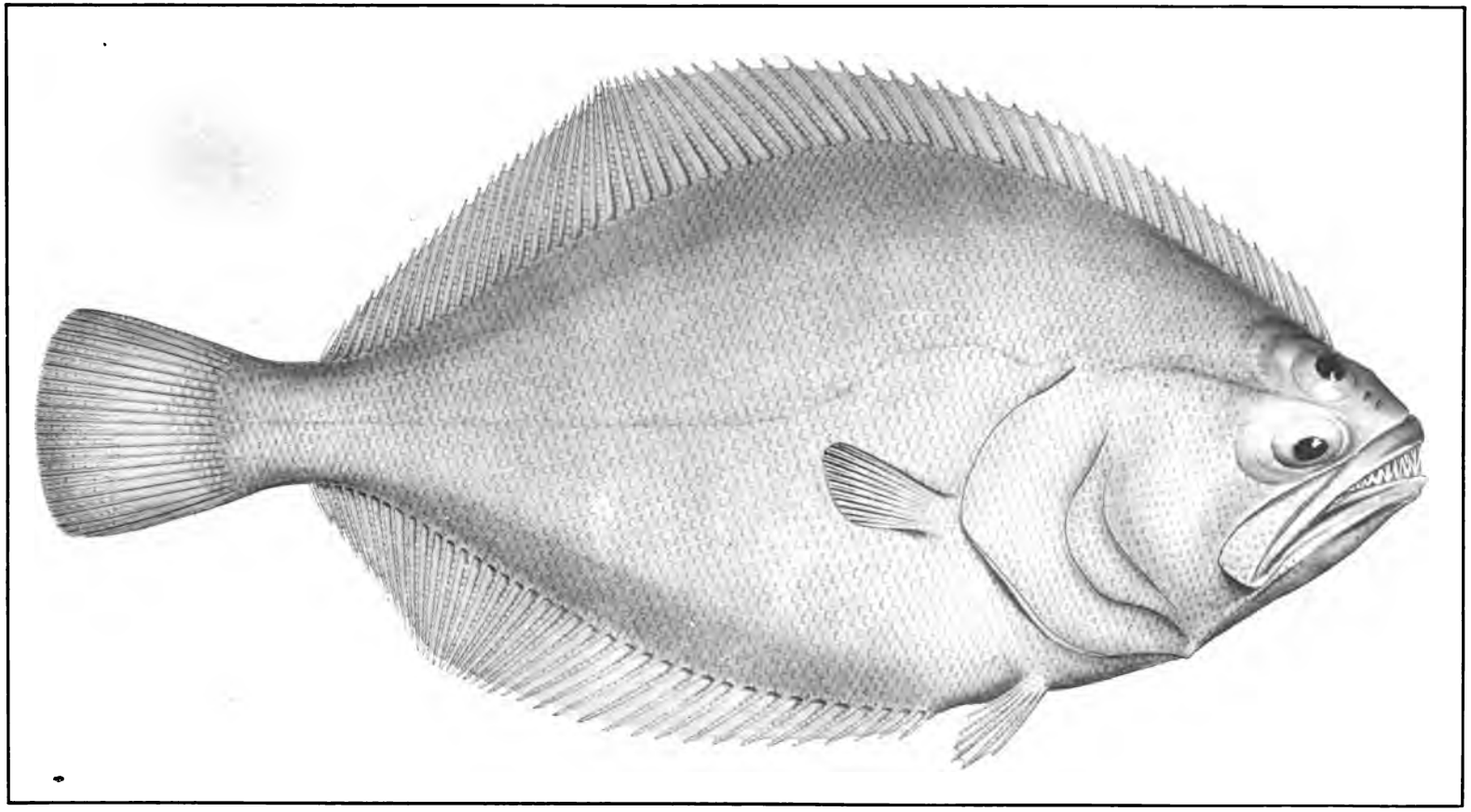

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UNIVERSITY OF CALIFORNIA PUBLICATIONS

BULLETIN OF THE DEPARTMENT OF

GEOLOGY

Vol. 5, No. 28, pp. 413–420 ANDREW C. LAWSON, Editor

THE PROBABLE TERTIARY LAND CONNECTION BETWEEN ASIA AND NORTH AMERICA.*

BY

ADOLPH KNOPF.

INTRODUCTION.

A land connection between northeastern Asia and northwestern America during a portion of Tertiary time has been postulated by paleontologists to explain certain faunistic problems. It has been accepted as probable and so charted on Willis' paleontologic map of Miocene North America.[1]

The present paper, which is partly based on personal familiarity with northwestern Alaska, undertakes to discuss the geologic evidence of such a land connection.

The portion of Alaska lying nearest to Asia has been designated the Seward Peninsula since the gold excitement of 1898, and a great increase in the geographic and geologic knowledge of that region has resulted from the investigations conducted by the United States Geological Survey subsequent to that date.[2] As those studies have concerned themselves mainly with the auriferous alluvia, many observations bearing upon broader geologic problems are scattered through the numerous economic and progress reports, where they are not readily available to those unfamiliar with the literature.

* Published by permission of the Director of the U. S. Geological Survey.

[1] Journ. Geol., 1909, p. 503.

[2] Bull. U. S. Geol. Survey No. 328, 1908, contains a compendium of the geography and geology of Seward Peninsula.

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GEOGRAPHY.[3]

The continents of Asia and North America lie in closest proximity to each other in latitude 65° north. Bering Strait, the body of water separating them, is fifty miles wide in its narrowest portion. Cape Prince of Wales in longitude 168° west forms the extreme western projection of North America; opposing it on the Asiatic side is the bold promontory of East Cape, the extreme eastern projection of Chukchi Peninsula. Lying approximately midway between these two headlands are the Diomede Islands, the larger of which, known as the Big Diomede, belongs to Russia, and the smaller, the Little Diomede, belongs to the United States. The islet called Fairway Rock lies a few miles to the southeast of the Diomedes.

Seward Peninsula is bounded on the north by Kotzebue Sound and the Arctic Ocean and on the south by Bering Sea and Norton Sound. It embraces an area of approximately 20,000 square miles, which is included mainly between meridians 161° and 168° west longitude and parallels 64° and 66½° north latitude.

As shown on the Coast and Geodetic Survey Chart, the 100-fathom line of Bering Sea starts at Unimak Island, the Aleutian Island lying at the southwest extremity of the Alaska Peninsula, and trends northwest to Cape Navarin on the Siberian Coast. North of this line Bering Sea is characterized by extreme shallowness, barely averaging 200 feet in depth, whereas to the south it abruptly attains a depth of 12,000 feet. The extreme shallowness persists through Bering Strait and prevails over a large portion of the Polar Sea lying to the north. It is to be noted of the Aleutians, which are held to mark off Bering Sea from the Pacific Ocean, that the westernmost islands rise directly from oceanic depths. In some speculations they are regarded as having afforded a bridge between Asia and America at some time in the past.

[3] The geographic relations including soundings of Bering Sea are best shown on Chart T, U. S. Coast and Geodetic Survey.

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GEOLOGY.

The oldest rocks of Seward Peninsula comprise various schists, limestones, and gneisses, forming the bedrock of the auriferous areas. They are regarded as probably of early Paleozoic age. In the northwestern part of the peninsula there is a large area of fossiliferous limestone, called the Port Clarence limestone, which on the basis of recent paleontologic study is known to range in age from Upper Cambrian to Upper Silurian.[4]

Near Cape Prince of Wales a belt of limestone and marble five miles wide trends northwest across the western extremity of the peninsula. Evidence secured by Collier[5] shows it to be of Mississippian age.

A stock of coarse porphyritic granite is intrusive into the limestone and is therefore of post-Mississippian age. It is in all probability pre-Cretaceous, like analogous occurrences in the eastern part of Seward Peninsula.[6] This granitic mass forms the youngest bedrock of that portion of the American continent lying in closest proximity to Asia. The Diomede Islands midway between the continents are composed of similar granite.

There are, however, scattered throughout the peninsula, small patches of unaltered sediments composed of conglomerates, sandstones, and shales, locally carrying seams of coal, of which the largest known is 88 feet thick. These rocks rest unconformably on the metamorphic terranes, and in the absence of fossil evidence are believed from their lithologic resemblance to other coal-bearing formations of Alaska to be of Cretaceous or Eocene (Kenai) age. On St. Lawrence Island, which lies about 150 miles south of Bering Strait and is the largest island in Bering Sea, Collier has discovered some coal-bearing sediments carrying plant remains.[7] A few conifers and dicotyledons were found, among which Knowlton has identified *Sequoia langsdorfii,* indicating Kenai age. This bit of evidence, incomplete and unsatisfactory as it is, is the most important yet discovered that bears

[4] Kindle, E. M., unpublished manuscript.

[5] Collier, A. J., Bull. U. S. Geol. Survey No. 328, 1908, p. 81.

[6] Oral communication by P. S. Smith.

[7] Unpublished information.

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on the question of a land connection between the continents during the early part of the Tertiary.

Rocks of Kenai age are known in widely separated parts of Alaska, and are of fluvial, lacustral, and possibly, in part, of estuarine origin. The Kenai flora indicates that temperate or subtropical conditions prevailed over Alaska in Upper Eocene time.

Extensive deposits of alluvial material occur throughout Seward Peninsula. They consist of sands, gravels and silts, and local accumulations of glacial debris. They have not yet been studied from a chronological standpoint. Logs of a species of spruce, the northern limit of which is now in the latitude of Sitka, and mammalian remains have been found in them, and indicate climatic conditions greatly different from those of the present.[8]

Scattered observations only are available concerning the adjacent Siberian coast. These concur in describing it as a bold mountainous region composed essentially of granitic rocks.

According to Suess,[9] Bogdanowitsch has investigated the geology of Chukchi Peninsula in some detail. He finds that the rocks are mainly of eruptive and metamorphic character, from which it may be concluded that they furnish little light on the problem under discussion.

From the foregoing brief resumé it is obvious that the record of the geologic history of the region as revealed by the sedimentary rocks is characterized by immense lacunae, and is practically a blank for the whole of the Tertiary period. Such further evidence as may be obtained must be afforded by the study of the physiographic evolution of the region.

Accumulating evidence shows that the physiographic history is complex in detail. It is unfortunately true that the peninsula has not been studied as a whole by any one observer, and consequently a comprehensive account has not yet been formulated. Certain broader facts, however, have been established, and from them may be drawn conclusions important to the present discussion.

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[8] The available information concerning the Pleistocene vertebrate fauna of Alaska has recently been assembled and discussed by C. W. Gilmore in Smithsonian Misc. Coll., vol. 51, 1908.

[9] Antlitz der Erde, vol. III, 2d part, 1909, p. 405.

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After the deposition of the coal-bearing sediments a long period of stability supervened, during which much of the peninsula was reduced to a peneplain. According to Brooks,[10] the age of this peneplain has not been determined, but it is probably the same as that of the Yukon plateau, which is known to have been developed in post-Kenai pre-Pliocene time. This old surface of erosion is now represented throughout the peninsula by flat-topped ridges and domes ranging in altitude from 800 to 2,400 feet. The level summits of the interstream areas blending into an even sky-line form a striking feature of the topography. In the western part of the peninsula, on the northern flank of Brooks Mountain at an altitude of 1,800 feet, the writer found remnants of well-rounded gravels, which can hardly be interpreted otherwise than as relics of an ancient drainage system. In the region of the Kotzebue Sound the flat-topped ranges are especially well developed and are rendered highly impressive by terraces, in places up to twelve in number and ranging in height from 10 to 100 feet scored upon their flanks.[11]

A finely preserved terrace of marine origin known as the York bench extends northwestward from Port Clarence to the apex of the continent. South of the York Mountains it bevels the upturned edges of the Port Clarence limestone, and attains a width ranging from a few hundred yards to four miles. "The surface of this bench," says Collier,[12] "is an almost perfect plain swept bare of gravel or other detrital material, but is covered in many places with yellow clay derived from the solution of the limestone." Between the York Mountains and Cape Mountain the bench merges with a prominent topographic feature known as the York Plateau, which constitutes a well-marked upland surface.[13]

At Cape Prince of Wales, the terrace which is there carved upon the granite of Cape Mountain has an elevation of 300 feet; fifteen miles eastward, at Kanauguk River, it attains a height of 700 feet; fourteen miles farther eastward at Lost River it

[10] Bull. U. S. Geol. Survey No. 328, 1908, p. 112.

[11] Moffit, F. H., Bull. U. S. Geol. Survey No. 247, 1905, p. 44.

[12] Prof. Paper U. S. Geol. Survey No. 2, 1902, p. 37.

[13] These features are well shown on the topographic maps accompanying Bull. U. S. Geol. Survey No. 328, 1908.

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stands at 600 feet; and in the vicinity of Port Clarence it sinks to 200 feet.[14] The uplift of the terrace was, therefore, accompanied by a considerable amount of warping, with the maximum deformation along the axis of the York Mountains. The streams flowing into Bering Sea have entrenched themselves in sharp canyons across the bench, and this topographic evidence affords the only clue to the age of the terrace. Locally some minor benches but a few feet above the sea-level can be noted, and testify that the general movement of uplift is still in progress.

Inspection of the topographic map is sufficient to show that the coastal plain bordering the Arctic Ocean between Cape Prince of Wales and Cape Espenberg is a region of depression. The York Plateau, which is broken off on its southern margin by sea cliffs overlooking Bering Sea, slopes gently northward to the Arctic Ocean and is buried under the Pleistocene alluvium. At Shishmaref Inlet, a large, shallow embayment from the Polar Sea, the lower courses of the streams are affected by tidal ebb and flow, and prove the recent submergence of the region.

The complex oscillations of the strand-line in the vicinity of Nome during the late Tertiary and Quaternary time have been revealed in unusual fullness of detail by the exploitation of the ancient auriferous beaches.[15] Five such beaches buried under the tundra of the coastal plain at depths ranging from five to one hundred feet have been discovered, the youngest of which is 78 feet above sea-level, and the oldest 34 feet below sea-level. Fossils are plentiful in the beach deposits, which consist of loose sands and gravels. Those from the beach standing at 78 feet above sea-level have been determined by W. H. Dall to be of Pliocene age and to indicate that warmer water conditions prevailed than obtain now in adjacent portions of Bering Sea.[16] According to the same authority, the fossils from the beach 34 feet below sea-level are of Upper Miocene or Pliocene age.[17] The geologic history as deciphered from the beaches

[14] Data based partly upon Collier's and partly upon the writer's observations.

[15] Smith, P. S., Bull. U. S. Geol. Survey No. 379, pp. 277-279.

[16] Am. Journ. Sci., 1907, vol. 23, p. 457.

[17] Unpublished information. *Cf.* Journ. Geol., 1909, p. 498.

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shows that the region in the vicinity of Cape Nome was depressed at least 112 feet below sea-level during the Pliocene and has only partly recovered from that submergence during Quaternary time.

CONCLUSIONS.

The stratigraphy of adjacent portions of Asia and America, so far as now known, throws little light on the question of whether a land connection between those continents ever existed during Cenozoic time. In fact, all the evidence from which conclusions of some positiveness can be drawn record only epochs of more widely spread submergence and increased separation of the continents. It has been determined beyond question that the uplift of submerged portions of the continental border was accompanied by marked deformation. During the upraising of the marine-wrought York bench a differential warping of 400 feet in a distance of fifteen miles was produced.

Dawson,[18] writing in 1894, believed that the available evidence pointed to a general submergence during the later Miocene, uplift of the present land areas at the close of the Miocene, and subaerial conditions, with possibly brief intervals of depression, during post-Miocene time. The evidence of the Miocene submergence, however, was based on the occurrence of the Nulato sandstone on the lower Yukon, which had been referred to the marine Miocene by Dall, but which subsequent work has shown to be of Upper Cretaceous age.[19]

The observations of the last decade show that it is unsafe to make wide-reaching generalizations embracing the whole region of Bering Sea and its environs. The diastrophic movements have been too complex, the oscillations of the strand line too frequent and localized, and the information concerning them too scanty. Recognizing those elements of uncertainty, we may sketch the Cenozoic history of the region as interpreted from the evidence now available.

[18] Dawson, G. M., Geological notes on some of the coasts and islands of Bering Sea and vicinity. Bull. Geol. Soc. Amer., Vol. 5, 1894, pp. 143 et seq.

[19] Brooks, A. H., Geography and Geology of Alaska: Prof. Paper U. S. Geol. Survey No. 45, 1906, p. 236.

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The Eocene and Miocene were apparently periods of comparative stability and were marked by the reduction of the region of Seward Peninsula to a peneplain. The submarine plateau of Bering Sea, which is considered by Dawson[20] as belonging physiographically to the continental plateau region, may have been evolved during those periods, and Asia and America connected by a land mass.

At the beginning of the Pliocene, Seward Peninsula possessed approximately its present shore line. In terms of the physiographic record the facts indicate that the peninsula possessed approximately its present outline at the time of the marine planation of the York bench. The York bench is undoubtedly older than the loose sands and gravels of the Nome beach deposits, and if we accept the age of the latter as determined paleontologically, is, therefore, of pre-Upper Miocene age. It is difficult to reconcile this great age with the splendid state of preservation of the marine terrace.

During the remainder of Cenozoic time the dominant movement affecting Seward Peninsula has been that of uplift. The crustal instability of the region, the known large differential warping that has accompanied elevatory movements, and the shallow depth of Bering Sea render it, however, highly probable that at various times brief periods of land communication have existed between the continents.

The general conclusion is therefore borne upon us that if the problems of the intercontinental migration of faunas demand periods of terrestrial communication between the two mainlands during Cenozoic time, the physical evidence, so far as now known, favors the probability of intervals of continuity of the adjoining land masses of Asia and North America.

[20] *Op. cit.*, p. 146.

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UNIVERSITY OF CALIFORNIA PUBLICATIONS

BULLETIN OF THE DEPARTMENT OF

GEOLOGY

Vol. 5, No. 29, pp. 421-437 ANDREW C. LAWSON, Editor

RODENT FAUNA

OF THE

LATE TERTIARY BEDS

AT

VIRGIN VALLEY AND THOUSAND CREEK, NEVADA

BY

LOUISE KELLOGG.

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INTRODUCTION.

The rodent forms described below represent a portion of the mammalian fauna collected during the summer of 1909 by a palaeontological expedition organized and financed by Miss Annie M. Alexander to carry on work in the later Tertiary beds of

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Virgin Valley and Thousand Creek, Humboldt County, Nevada. The collections made by the expedition have been presented to the University of California by Miss Alexander.

The writer is greatly indebted to Professor John C. Merriam for the privilege of working over the material, and for his courtesy and assistance in the work.

With the exception of isolated specimens, the rodent remains were found only in a few localities. In these places the bones were scattered abundantly over small areas, and the collectors by dint of hard labor on their hands and knees, sifted over every inch of the ground in order that the smallest bones and teeth should not be overlooked.

As rodents are generally restricted in their geographic range, and are relatively good indicators of climate and other physical conditions, they are an important factor in the work of building up a picture of the conditions which obtained in any region in past time; and it is hoped that the following list of forms will help materially in determining the nature of the environment in which mammalian life existed in the Virgin Valley and Thousand Creek region during the late Tertiary.

ARCTOMYS NEVADENSIS, n. sp.

Figs. 1*a*, 1*b* and 2.

Type specimen no. 12506, Univ. Calif. Col. Vert. Palae., anterior portion of a left ramus of the lower jaw with P_4 and M_1 intact, and the incisor broken off where it emerges from the jaw. From locality no. 1105, near Thousand Creek, Humboldt County, Nevada.

Specific Characters.—Incisors small in proportion to the other teeth. P_4 and M_1 relatively large, more nearly square in cross-section, and set more obliquely in the jaw than in other species. A small ridge on the anterior face of P_4 instead of a tubercle. The symphysis ends posteriorly in front of the mental foramen instead of extending back of it as in other species.

General Description.—P_4 and M_1 may be said to consist of two distinct portions, an anterior formed by a large protoconid and metaconid with parastylid between, and a posterior consist-

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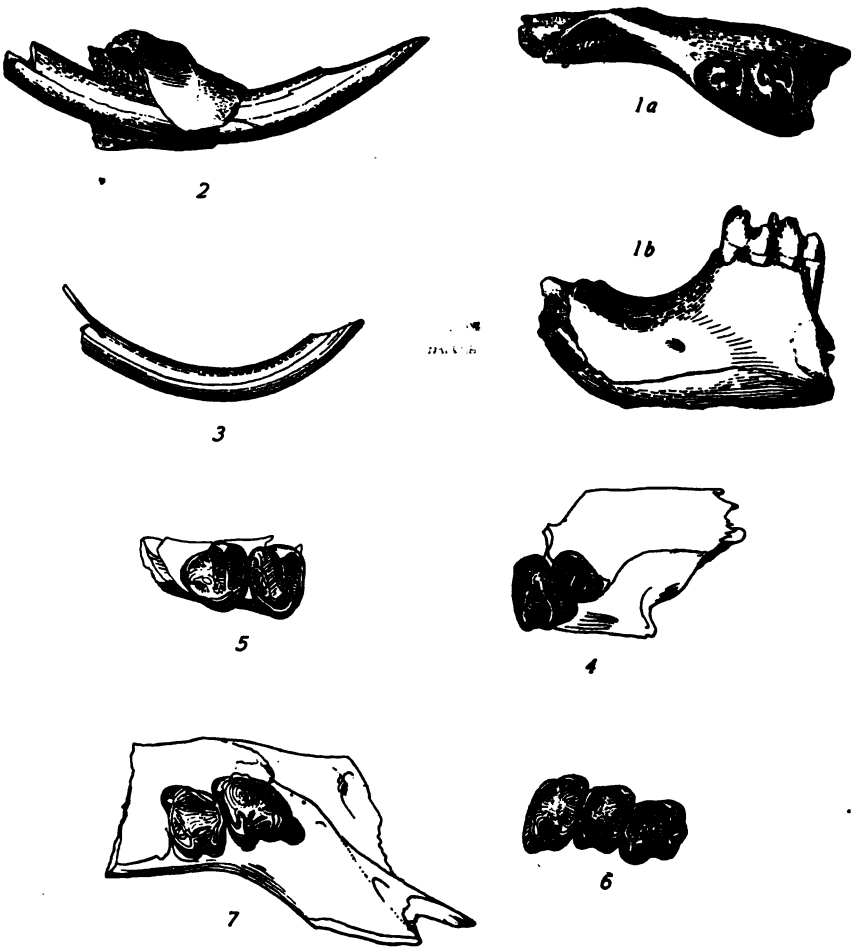

Figs. 1*a* and 1*b*.—*Arctomys nevadensis.* Portion of the left mandible with P_4, M_1, and the base of the incisor. No. 12506, natural size.
Fig. 1*a*, superior view; fig. 1*b*, lateral view.

Fig. 2.—*Arctomys nevadensis.* Portion of right mandible with incisor. No. 12544, natural size.

Fig. 3.—*Arctomys minor.* Portion of larger incisor. No. 12538, natural size.

Fig. 4.—Portion of maxillary with left P^3 and P^4. No. 12538, × 2.

Fig. 5.—*Arctomys minor.* Right M^2 and M^3. No. 12538, × 2.

Fig. 6.—*Arctomys minor.* Right P_4, M_1 and M_2. No. 12538, × 2.

Fig. 7.—*Arctomys minor.* Portion of left mandible with M_2 and M_3. No. 12538, × 2.

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ing of a strongly curved ridge formed by the entoconid, hypoconulid, and hypoconid. In both teeth the metaconid is much higher than the protoconid, and in P_4 it is decidedly recurved. There is a fossette between the protoconid and metaconid. The entoconid and hypoconulid form a quarter-circle, running from the metaconid around to the triangular hypoconid, and enclosing a deep pit containing small tubercles. There is also a ridge between the base of the hypoconid and the protoconid. All the cones are set obliquely to the median line of the jaw, but those of M_1 are more oblique than those of P_4. The incisor is considerably flattened transversely and is small in proportion to the other two teeth.

A specimen, no. 12544, comprising the right P_4, half of left P_4, and a portion of the right ramus of a lower jaw with incisor, from locality no. 1105, on Thousand Creek, is evidently to be referred to *A. nevadensis*. P_4 of this specimen is similar in pattern to that of *A. nevadensis*, but larger. The anterior portion is much broader, while the heel is comparatively small and rather pointed. The incisor is small in proportion to the premolar, although somewhat larger than that of *A. nevadensis*.

MEASUREMENTS.

	No. 12506	No. 12544	*A. primigenia*
P_4, median anteroposterior diameter	5.8 mm.	7.4 mm.	6.5 mm.
M_1, median anteroposterior diameter	6.3		4.6
P_4, transverse anterior diameter	5.1	6.0	4.3
M_1, transverse anterior diameter	6.4		5.8
M_1, transverse posterior diameter	6.9		5.6
P_4, transverse posterior diameter	5.9		5.6
P_4, anteroposterior diameter of heel	3.3		2.4
M_1, anteroposterior diameter of heel	4.4		3.2
Lower incisor, anteroposterior diameter	6.4	6.9	6.7
Lower incisor, transverse diameter	4.1	4.6	
Length of diastema	19.1		13.3
Base of P_4 to mental foramen	11.2		10.7
Width of ramus over mental foramen	15.2		11.6

Comparison with other Species of Arctomys.—From the arrangement of the tubercles of the teeth it is evident that this specimen must be referred to the genus *Arctomys* rather than any other genus of the Sciuridae. The cheek teeth have three

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anterior tubercles and a heel consisting of a curved ridge, while *Plesiarctomys, Sciurus, Sciuroides, Pseudosciurus,* and *Spermophilus* all have four tubercles which tend to pair anteriorly and posteriorly into transverse ridges and form a square tooth.

This form is nearest to *Arctomys primigenia,* an extinct species from the Pleistocene of Paris, the chief difference between the two being that *A. primigenia* has a distinct, separate tubercle on the anterior face of P_4, while in *A. nevadensis* there is a ridge starting from the base of the metaconid[1] and showing only the slightest indication of a separation where it joins the protoconid. Other points of difference are in the larger size of P_4 and M_1, in *A. nevadensis,* their more nearly square form and more oblique setting; the smallness of the incisor in proportion to the other teeth; and in the symphysis ending posteriorly in front of the mental foramen instead of back of it as in *A. primigenia.* From the living species, *A. monax, A. flaviventer, A. dacota,* and from the extinct species, *A. vetus, A. nevadensis* differs in its greater size; more particular differences being that *A. monax* has the anterior tubercles of the teeth much lower, and *A. flaviventer* has a low metaconid, the teeth are more nearly square and the tubercles not so oblique. As compared with *Palaearctomys montanus,* this species shows small incisors and large P_4 and M_1, and the jaw itself is larger and heavier.

ARCTOMYS MINOR, n. sp.

Figs. 3, 4, 5, 6, and 7.

Type, no. 12538, Univ. Calif. Col. Vert. Palae. Left P^3 and P^4 with part of the maxilla; right M^2 and M^3 with portion of the lower jaw; right P_4, M_1, and M_2; and the anterior portions of the upper and lower incisors. From locality no. 1083 at Thousand Creek, Humboldt County, Nevada.

Specific Characters.—P_4 has a slender metaconid not much higher than the protoconid and the two are connected by a ridge, whereas in other species both tubercles are high and not connected by a ridge. Protoconid and hypoconid far apart with

[1] In this paper, the nomenclature used in descriptions of lower premolar teeth is the same as that commonly followed in designation of the tubercles of lower molars.

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ridge between, instead of close together. Ridge on anterior face small. Entoconid ridge rounded rather than square. The incisors and P_4 are large in proportion to other teeth.

General Description.—P^3 is a round, single-rooted tooth, comparatively smaller than P^4 and consisting of one high cone on the outer, posterior side, around which circle two small ridges. P^4 consists of one low anterior and two posterior ridges, set transversely to the median line of the jaw, and with a rounded tubercle on the inner side between the two ridges, from the base of which a smaller ridge runs to the posterior edge of the third transverse ridge; M^2 has three transverse ridges, the middle one slightly higher than the other two and running up into a tubercle on the outer edge of the tooth and an inner tubercle which seems to be a continuation, toward the back of the tooth, of the central ridge. M^3 consists of two transverse ridges, the second running up into a tubercle with an inner tubercle extending from it, and a low, rounded heel with several flattened ridges. P_4 has a protoconid and metaconid, the latter somewhat higher and connected with the protoconid by a ridge, and directly between them anteriorly and set low on the tooth, a curved ridge, almost the equivalent of a tubercle, behind which is a small pit. The hypoconid is connected with the protoconid by a ridge and the ridge of the entoconid curves around to the base of the metaconid, the whole heel being slightly lower than the protoconid. M_1, M_2, and M_3 have a high metaconid with a small accessory ridge merging into that of the entoconid, and a low protoconid and hypoconid with a fossette between.

A comparison of *A. minor* with specimen no. 3079 of the California Museum of Vertebrate Zoology, which is a left ramus of the lower jaw with incisor and P_4, found at the head of Big Creek, Humboldt County, Nevada, and referred tentatively to *A. flaviventer,* shows the following specific differences. In no. 3079 the protoconid and metaconid are much higher, the latter is more swollen, and there is no ridge between them, the two edges meeting at a sharp angle; the protoconid and hypoconid are closer together; the anterior ridge is longer and more bulging; and the entoconid ridge is square, rather than rounded.

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MEASUREMENTS.

	No. 12538	No. 3079[2]
P_4, anteroposterior diameter	4.2 mm.	4.8 mm.
P_4, transverse diameter of anterior portion	3.4	3.7
P_4, transverse diameter of anterior ridge	1.1	2.2
Incisor, transverse diameter	2.7	3.0
Incisor, anteroposterior diameter	4.1	4.2

A comparison with *A. monax* shows that *A. minor* has a more decided ridge on the anterior face of P_4, the metaconid is higher and the protoconid and hypoconid farther apart, the heel of the tooth is not so low, and none of the lower teeth slope downward on the inner side. The incisors and P_4 are large in proportion to the other teeth. M^2 and M^3 are set straight in the jaw and not sloped downward and outward.

A. minor differs from *Palaearctomys macrorhinus* in having smaller incisors and a larger M^3, with two ridges instead of one. M^2 has three ridges instead of two. The incisors lack the longitudinal furrows given as a generic character of *Palaearctomys*.

MEASUREMENTS.

	A. minor	*P. macrorhinus*
Anteroposterior diameter of larger incisor	4.2 mm.	
Anteroposterior diameter of smaller incisor	4.1	7.0 mm.
Transverse diameter of larger incisor	3.3	5.0
Transverse diameter of smaller incisor	2.7	
M^1, anteroposterior diameter	4.3	4.2
M^2, anteroposterior diameter	3.4	3.5
M^3, anteroposterior diameter	4.2	3.7
M^1, transverse diameter	3.3	3.4
M^2, transverse diameter	4.1	4.0
M^3, transverse diameter	4.1	3.5

CITELLUS, sp.

Fig. 8.

No. 12570, Univ. Calif. Col. Vert. Palae., a worn M_1 from locality no. 1103 at Thousand Creek, Humboldt County, Nevada.

This tooth does not exhibit any specific characters distinguishing it from *Callospermophilus trepidus*, a new species obtained

[2] Calif. Mus. Vert. Zool.

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from the head of Big Creek, Humboldt County, Nevada, excepting possibly a more nearly square form; but it is reasonable to suppose that with more material the fossil form would show some distinct differences between it and the living species.

MEASUREMENTS.

	No. 12570	*Callospermophilus trepidus*
M_1, anteroposterior diameter	1.9 mm.	1.5 mm.
M_1, transverse diameter	1.9	2.3

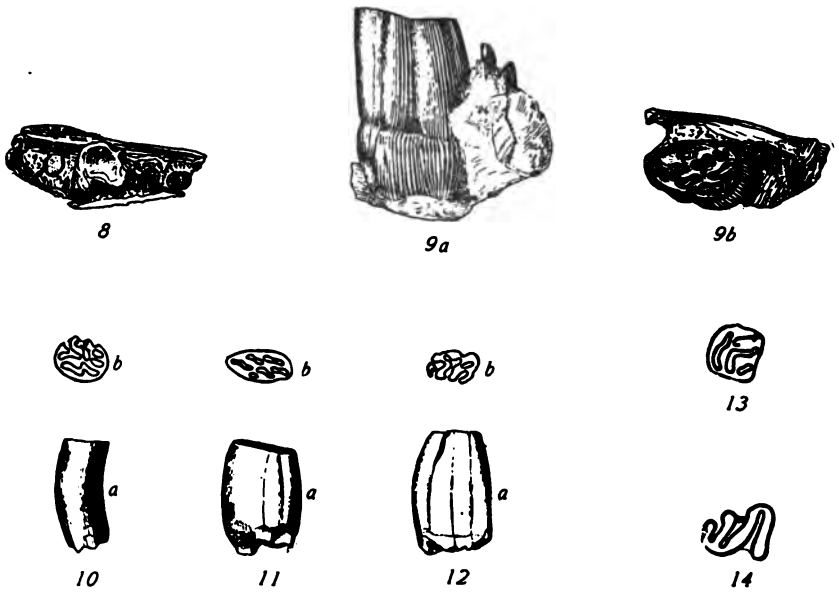

Fig. 8.—*Citellus*, sp. Portion of right mandible with M_1. No. 12570, × 4.

Figs. 9*a* and 9*b*.—*Mylagaulus monodon*. Left P_4. No. 11572, × 1½. Fig. 9*a*, lateral view; fig. 9*b*, superior view.

Figs. 10, *a* and *b*.—*Mylagaulus monodon*. Left P^4. No. 11878, natural size. Fig. *a*, lateral view; fig. *b*, superior view.

Figs. 11, *a* and *b*.—*Mylagaulus pristinus*. Right P_4. No. 12580, natural size. Fig. *a*, lateral view; fig. *b*, superior view.

Figs. 12, *a* and *b*.—*Mylagaulus pristinus*. Left P_4. No. 12579, natural size. Fig. *a*, lateral view; fig. *b*, superior view.

Fig. 13.—*Eucastor lecontei*. P_4. No. 11085, × 1½.

Fig. 14.—*Dipoides*, sp. Left P_4. No. 12536, × 1½.

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APLODONTIA ALEXANDRAE Furlong.

This is a small species described by Mr. E. L. Furlong in the University of California Publications in Geology, vol. 5, p. 398. The most important specific character is the presence of a prominent style on the inner posterior portion of the lower teeth, instead of in the median region. It occurs in the Tertiary beds at Virgin Valley, and also at Thousand Creek.

MYLAGAULUS MONODON Cope.

Figs 9*a*, 9*b*, 10, *a* and *b*.

No. 11878, left P^4 from locality no. 1098, Thousand Creek; and nos. 11572, a left P_4, and 11662, a right P_4, from locality no. 1065 in Virgin Valley, Humboldt County, Nevada.

No. 11878, although an unworn tooth, exhibits a pattern that with age would evidently resemble that shown in the figure of *Mylagaulus monodon*, no. 9043, as presented by Matthew in the Memoirs of the American Museum of Natural History.[3]

Nos. 11572 and 11662 represent teeth in different stages of wear, the former being worn and the latter unworn, so that they do not agree exactly in the enamel pattern. They are referred to *Mylagaulus monodon* Cope, although the number and arrangement of the lakes do not show an exact resemblance to any figures of that species shown.

MEASUREMENTS.

	No. 11878	No. 11572	No. 11662
P^4, anteroposterior diameter	7.5 mm.		
P^4, transverse diameter	6.0		
P_4, anteroposterior diameter		8.8 mm.	8.6 mm.
P_4, transverse diameter		5.2	5.0

MYLAGAULUS PRISTINUS Douglass.

Figs. 11, *a* and *b*; 12, *a* and *b*.

Nos. 11843, 11684, 11540, left P_4, from locality no. 1090. No. 12579, a left P_4; and no. 12580, a right P_4; both from locality no. 1095, Virgin Valley, Humboldt County, Nevada.

[3] Mem. Am. Mus. Nat. Hist., vol. 1, p. 379, fig. 5.

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In the number and arrangement of the lakes, nos. 11843, 11684, 11540 correspond to *Mylagaulus pristinus* Douglass as figured in the Annals of the Carnegie Museum.[4] They also agree in size, except for the height of no. 742, which is greater on account of its being an unworn tooth, while these specimens are those of old individuals with roots closed at the bottom. No. 12579 is an unworn tooth very much like P_4 of fig. 26*b*.

MEASUREMENTS.

	No. 12579	No. 11843	No. 11684	No. 11540
P_4, anteroposterior diameter	7.2 mm.	7.0 mm.	7.4 mm.	6.7 mm.
P_4, transverse diameter	4.5	3.7	4.3	3.9
P_4, height	17.2	10.8	11.3	11.3

EUCASTOR LECONTEI (Merriam).

Fig. 13.

Eucastor (Sigmogomphius) lecontei was described as generically different from *Eucastor tortus* Leidy on account of the open character of the folds, the relatively greater size of the molars, the relatively small size of the triturating surface of P^4, and the absence of M^3. In his description of *Eucastor*, Leidy makes no reference to a third molar, although the figure shows what is perhaps an alveolus for a fourth tooth on the right side. As the presence of isolated lakes instead of open folds is an age character, we may say that *Sigmogomphius* is specifically different from *Eucastor tortus* on account of the relatively greater size of the molars and the relatively small size of the triturating surface of P^4, but that there does not seem to be sufficient evidence to separate them generically.

A specimen, no. 11085, a right P^4, from locality no. 1090, Virgin Valley, Humboldt County, Nevada, is so close to *Eucastor lecontei* that it can hardly be separated from it specifically, although it is a more nearly square tooth, P^4 of *E. lecontei* being triangular with the apex at the inner posterior corner.

MEASUREMENTS.

	No. 11085	*E. lecontei* Type specimen
P^4, anteroposterior diameter	4.6 mm.	4.7 mm.
P^4, transverse diameter	4.9	5.1

[4] Ann. Carneg. Mus., vol. 2, p. 188, fig. 26*c* (no. 742).

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DIPOIDES, sp. probably new.

Fig. 14.

No. 12536, Univ. Calif. Col. Vert. Palae., left P_4 and M_1, from locality no. 1103, Thousand Creek, Humboldt County, Nevada.

These two teeth, P_4 and M_1, are very like those of *Dipoides problematicus* Schlosser found in the Bohnerzen of Salmandingen and Melchingen. The great difference in the geographic location of the two would seem a reasonable ground for specific separation taken in connection with the fact that the teeth of the American form are larger.

MEASUREMENTS.

	No. 12536	*D. problematicus*
P_4, anteroposterior diameter	5.9 mm.	4.8 mm.
M_1, anteroposterior diameter	4.5	4.1
P_4, transverse diameter	4.6	4.6
M_1, transverse diameter	4.8	4.2

ENTOPTYCHUS MINIMUS, n. sp.

Fig. 15.

Type no. 12569, Univ. Calif. Col. Vert. Palae., portion of left ramus of the lower jaw with P_4, M_1, M_2. Locality no. 1103 at Thousand Creek, Humboldt County, Nevada.

Specific Characters.—Extremely small size.

Description and Comparison.—The three teeth of this specimen are practically similar, being prismatic and with a deep fold on the inner side running almost to the outer margin, but the premolar is distinguished by a slight fold on its outer side also. In their half-worn state they show a tendency to form in the center a tube, entirely surrounded by enamel, a condition which is described by Dr. Matthew as being characteristic of this genus. The specimen is very much smaller than any of those of *Entoptychus minor* from the John Day Beds, although the tooth pattern is quite similar.

MEASUREMENTS.

	No. 12569
P_4, anteroposterior diameter	1.0 mm.
M_1, anteroposterior diameter	0.9
M_2, anteroposterior diameter	0.9
P_4, transverse diameter	1.2
M_1, transverse diameter	1.2
M_2, transverse diameter	1.3
Height of ramus at P_4	3.2

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15

16

17a

17b

18

Fig. 15.—*Entoptychus minimus.* Portion of left mandible with P_4, M_1, and M_2. No. 12569, × 4.

Fig. 16.—*Peromyscus antiquus.* Portion of left mandible with complete molar series. No. 12471, × 4.

Figs. 17*a* and 17*b*.—*Diprionomys parvus.* Portion of right mandible with incisor, P_4 and M_1. No. 12566, × 4.

Fig. 17*a*, lateral view; fig. 17*b*, superior view.

Fig. 18.—*Diprionomys magnus.* Fragments of left mandible with P_4, M_1, and M_2. No. 12567, × 4.

PEROMYSCUS ANTIQUUS, n. sp.

Fig. 16.

Type no. 12571, Univ. Calif. Col. Vert. Palae., a left ramus of the lower jaw with complete molar series, incisor broken, and posterior portion lacking. Cotype no. 12572, a right ramus of the lower jaw with incisor present, no molar teeth, and the posterior portion gone. Locality no. 1103 at Thousand Creek, Humboldt County, Nevada.

Specific Characters.—Its large size distinguishes it from *Peromyscus californicus* but the tooth pattern is practically identical, except that M_2 and M_3 have a ridge on the anterior face which is present in M_2 of *P. californicus* but not in M_3.

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MEASUREMENTS.

	No. 12571	No. 12572	*P. californicus*
M_2, anteroposterior diameter	2.0 mm.		1.8 mm.
M_2, anteroposterior diameter	1.6		1.3
M_3, anteroposterior diameter	1.4		.9
M_1, transverse diameter	1.3		1.1
M_2, transverse diameter	1.4		1.1
M_3, transverse diameter	1.3		.8
Height of ramus over mental foramen	2.4	2.7 mm.	2.4
Height of ramus at M_1	3.7	3.8	3.6
Length of tooth row	5.6	5.8	4.3
Incisor, transverse diameter		.8	.6
Incisor, anteroposterior diameter		1.3	1.1

PEROMYSCUS ?, sp.

No. 12573 and no. 12574, portions of two rami of lower jaws from locality no. 1103 at Thousand Creek, Humboldt County, Nevada, without teeth but so small as to make them evidently specifically different, although no very accurate conclusions can be drawn without the teeth.

MEASUREMENTS.

	No. 12573	No. 12574
Length of tooth row	3.7 mm.	3.8 mm.
Height of ramus over mental foramen	2.0	1.8
Height of ramus at M_1	2.9	2.8

DIPRIONOMYS PARVUS, n. gen. and sp.

Figs. 17*a*, 17*b*.

Type no. 12566, Univ. Calif. Col. Vert. Palae., anterior portion of a right ramus of the lower jaw with incisor, P_4, M_1. The beginning of the angle and coronoid process are indicated, but the rest of the posterior portion of the ramus is lacking. From locality no. 1103 at Thousand Creek, Humboldt County, Nevada.

Generic and Specific Characters.—The angle of the ramus does not turn inward and downward, but continues in a line with the anterior portion of the jaw, and the coronoid process rises abruptly from behind M_3, with no depression for the dental foramen. The incisor is small, M_3 is smaller than M_2, and the tooth row is long in proportion to the rest of the jaw.

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Description and Comparison.—P_4 of this specimen is made up of two distinct but connected columns with two roots; while M_1 is a prismatic column, slightly flattened anteroposteriorly, and with an indication of a fold on the inner side. The enamel of the incisor comes well around to the outer side. The alveolus of M_2 indicates that it must have been of about the same size as M_1, but the broken end of M_3 shows a much smaller tooth. A comparison with specimens of *Perodipus* shows that the two have teeth of a fairly similar character, although in the *Perodipus* generally P_4 does not show two distinct columns, especially in worn teeth; M_3 is not so much smaller than M_2; the enamel of the incisor does not come around to the outer side; and the folds of the molars vary, being sometimes lacking entirely, sometimes indicated on the outside and in a few cases both on the inside and outside. The jaw of *D. parvus* is smaller than in any specimen of *Perodipus* and yet the tooth row is longer. In *Perodipus* the angle of the ramus turns inward sharply, and back of M_3 the dental foramen is set in a deep pit. *D. parvus* shows more affinity with the genus *Perognathus* in jaw structure and even in the pattern of the teeth, but its teeth are prismatic while those of *Perognathus* are short-rooted.

MEASUREMENTS.

	No. 12566
P_4, anteroposterior diameter	1.4 mm.
M_1, anteroposterior diameter	1.2
P_4, transverse diameter	1.3
M_1, transverse diameter	1.4
Incisor, transverse diameter	0.7
Incisor, anteroposterior diameter	1.0
Length from anterior end of incisor to posterior end of tooth row	10.5
Height of jaw below P_4	3.2

DIPRIONOMYS MAGNUS, n. sp.

Fig. 18.

Type no. 12567, Univ. Calif. Col. Vert. Palae., a fragment of a left ramus of the lower jaw with P_4, M_1, M_2, and a groove indicating the size of the incisor. Cotype no. 12568, a portion of a left ramus of the lower jaw with P_4 and a fragment of the incisor. Locality no. 1103 at Thousand Creek, Humboldt County, Nevada.

Specific Characters.—Larger incisor and deeper fold on inner

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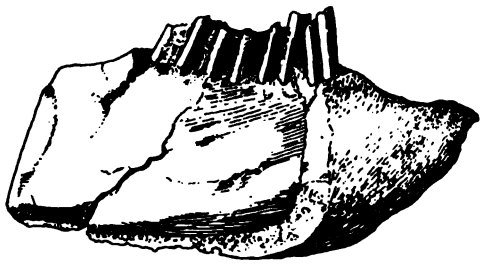
side of M_1, and M_2, than in *D. parvus*. The nature of the fold may be due in part to age.

MEASUREMENTS.

	No. 12567	No. 12568
P_4, anteroposterior diameter	1.8 mm.	1.7 mm.
M_1, anteroposterior diameter	0.9	
M_2, anteroposterior diameter	0.8	
P_4, transverse diameter	1.5	1.5
M_1, transverse diameter	1.6	
M_2, transverse diameter	1.6	
Incisor, transverse diameter		1.5
Incisor, anteroposterior diameter		1.6



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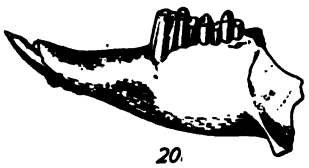
19b



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Figs. 19*a* and 19*b*.—*Palaeolagus nevadensis*. Portion of right mandible with P_3, P_4, M_1, and M_2. No. 12575, × 4.

Fig. 19*a*, lateral view; fig. 19*b*, superior view.

Fig. 20.—*Lepus vetus*. Portion of left mandible with incisor, P_3, P_4, M_1, and M_2. No. 12565, natural size.

PALAEOLAGUS NEVADENSIS, n. sp.

Figs. 19*a*, 19*b*.

Type no. 12575, Univ. Calif. Col. Vert. Palae., a portion of a right ramus of the lower jaw with molar series complete except for M_3. Locality no. 1065 at Virgin Valley, Humboldt County, Nevada.

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Specific Characters.—Small size of teeth. Molar columns triangular rather than approximately circular in cross-section.

Description.—This species is referred to the genus *Palaeolagus* because P_3 consists of one main column with a groove on its external face and the other premolars and molars are made up of two columns in anteroposterior relation.

P_3 is nearest that of *P. haydeni,* but the groove is further back. The molars of this specimen differ also in that the columns are irregularly triangular in cross-section with the apex cut off where they meet, instead of the perfectly regular cylindrical columns of *P. haydeni.* Its small size also easily distinguishes it as a different species.

MEASUREMENTS.

	No. 12575
P_3, anteroposterior diameter	.09 mm.
P_3, transverse diameter	1.4
P_4, anteroposterior diameter	1.5
P_4, transverse diameter	1.7
M_1, anteroposterior diameter	1.5
M_1, transverse diameter	1.8
M_2, anteroposterior diameter	1.8
M_2, transverse diameter	1.8

LEPUS VETUS, n. sp.

Fig. 20.

Type no. 12565, Univ. Calif. Col. Vert. Palae., portion of a left ramus of the lower jaw with incisor, P_3, P_4, M_1, M_2, the posterior portion broken off behind M_3. Cotype no. 11571, a portion of a right ramus of the lower jaw with a complete molar series. No. 12565 is from locality no. 1100 at Thousand Creek, Humboldt County, Nevada. No. 11571 is from locality no. 1065 at Virgin Valley, Humboldt County, Nevada.

Specific Characters.—Small size of jaw in proportion to size of teeth and length of tooth row. Incisor small in proportion to jaw.

General Description.—The molar teeth of this species present a close resemblance in size and pattern to those of *Lepus campestris townsendi,* but the incisor is much smaller, the diastema shorter, and the whole ramus is smaller and slighter.

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MEASUREMENTS.

	No. 12565	No. 11571	*L. townsendi*
P_3, anteroposterior diameter	2.9 mm.	3.1 mm.	3.2 mm.
P_4, anteroposterior diameter	2.7	2.6	2.8
M_1, anteroposterior diameter	2.4	2.7	2.8
M_2, anteroposterior diameter	2.6	2.5	2.3
M_3, anteroposterior diameter		2.0	
P_3, transverse diameter	2.8	2.5	3.3
P_4, transverse diameter	3.2	3.0	3.3
M_1, transverse diameter	3.1	3.1	3.1
M_2, transverse diameter	2.8	3.1	3.0
M_3, transverse diameter		2.0	2.9
Length of diastema	14.1		17.5
Incisor, transverse diameter	2.5		2.7
Incisor, anteroposterior diameter	1.9		2.2

Issued July 13, 1910.

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UNIVERSITY OF CALIFORNIA PUBLICATIONS

BULLETIN OF THE DEPARTMENT OF

GEOLOGY

Vol. 5, No. 30, pp. 439–448 ANDREW C. LAWSON, Editor

WADING BIRDS
FROM THE
QUATERNARY ASPHALT BEDS
OF
RANCHO LA BREA

BY

LOYE HOLMES MILLER.

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INTRODUCTION.

Comment has previously been made[1] on the unbalanced avifauna of the Rancho La Brea beds. Accepting the almost unavoidable conclusion that the herbivorous mammals found there were attracted in some measure by water, it seems most strange that the wading birds should be so poorly represented in the collections from these beds. Thus far there have been discovered in the large mass of material excavated by the University of California, but five species of the wading birds. Of these five species, three are represented by but one individual each. It is of interest also to note that fourteen out of a possible seventeen

[1] Miller, L. H., Univ. Calif. Publ. Geol., vol. 5, no. 21; also Condor, Jan., 1910.

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individuals represent a subfamily, the Ciconiinae, which is at present foreign to the region.

In the following description of these remains it was found necessary to establish two new species. It was considered inadvisable to establish a new genus of stork, although the species *maltha,* here referred to the genus *Ciconia,* is intermediate in the sum of its characters between *Ciconia* and *Euxenura.* The generic distinction between *Euxenura* and *Ciconia* is based largely on external features, and even these features are considered by some students to exhibit insufficient differences to warrant the recognition of the separate genus *Euxenura.* Conceding that the differences between the existing forms are of generic value, the form under discussion would not agree with either genus, and a new genus would be necessary. While there is little question that, were the asphalt stork restored to us in its entirety, it would possibly exhibit characters sufficient for its generic distinction, yet for the sake of simplicity it is referred, in the absence of those superficial characters, to the genus *Ciconia.*

CICONIIDAE, STORKS.

CICONIA MALTHA, n. sp.

Type specimen no. 11202; cotypes nos. 11237, 12529, 12527, 12532, and 12526, Univ. Calif. Col. Vert. Palae. The remains representing this species are somewhat fragmentary on the whole, but some very characteristic parts have been preserved,—namely, the coracoid, tarso-metatarsus, proximal and distal ends of the tibio-tarsus, and half of the furcula. To these parts there was added, through the kindness of Dr. C. O. Esterly of Occidental College, the middle portion of the beak, including the nostrils.

Aside from their separation in place in the deposits, the specimens show such duplication as to prove that more than one individual is represented. The homogeneity of characters, however, is sufficient to indicate their specific identity. The size is about the same as that of *Euxenura maguari,* from which species it differs in the details of each bone represented.

Tarsus.—This bone is represented in the asphalt material by one complete specimen, no. 11202, bearing an exostosis, and by

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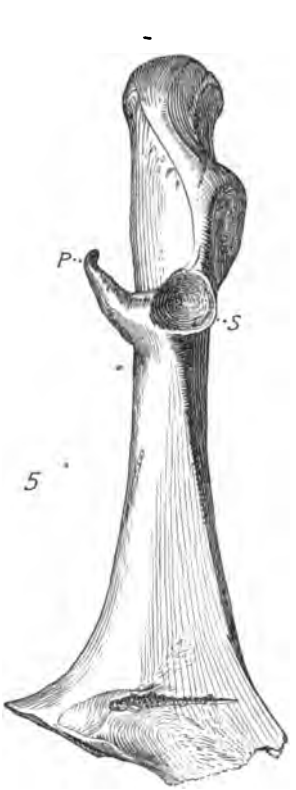

Figs. 1 to 5.—*Ciconia maltha.* All figures approximately natural size .

Fig. 1.—Left tarso-metatarsus seen from above. Type specimen no. 11202.

Fig. 2.—Left tarso-metatarsus seen from below.

Fig. 3.—Distal end of tibio-tarsus seen from in front. No. 12527.

Fig. 4.—Distal condyles of the same seen from below. *T*, tubercle on osseous bridge.

Fig. 5.—Coracoid from dorsal side. No. 11237. *S*, scapular facet; *P*, praecoracoid process.

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proximal and distal fragments. The entire bone is almost exactly equal in length to the specimen of *Euxenura* at hand. The shaft is markedly more slender, the head less expanded, but the foot is equal in width though less robust in the size and strength of the condyles. Seen from in front the depression down the front of the shaft is less abruptly overhung by the head; the inner profile of the head is less obliquely beveled off; the upper part of the shaft is less deeply and widely excavated. Seen from the inner side, the head is more compressed; the hypotarsus is much lower down; the inner ridge of the hypotarsus is more salient at its proximal end, a condition which is reversed in *Euxenura* and in *Ciconia alba*. Seen from the rear the shaft is flatter and less ridged in the proximal part, and merges more abruptly into the head, giving a more concave outer profile in this region. This point also distinguishes the form from *C. alba*. The intercotylar tuberosity appears to be much more prominent because the surface drops more abruptly from front to rear; the transverse crest passing between the superior extremities of the hypotarsal ridges slopes from within outward, being higher at its inner end. In this respect the form agrees with *C. alba* and is distinguished from *Euxenura*. The outer hypotarsal ridge is dropped further below the inner than in *Euxenura*.

Seen from the outer side the head agrees with *Ciconia alba* in being less canted forward on the shaft. The slope backward from the tuberosity shows a steeper profile than in *Euxenura*. The postero-lateral oblique surface for the attachment of articular ligaments is much more sharply defined in both *C. maltha* and *C. alba* than in *Euxenura*. The slightly oblique intermuscular ridge passing down the bone at this point in both *Euxenura* and *C. alba* is entirely wanting in the type. This feature is hardly due to corrosion, as the more exposed angles are very sharply defined.

Seen from the end the margins of the articular facets are more clearly cut, the space between their posterior margins is greater, and the depression between the articular portion and the hypotarsus becomes a deep pit marked posteriorly by a pronounced ridge. In this group of characters *C. maltha* and *C. alba* are distinct from *Euxenura*. The hypotarsal ridges are

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seen in section from this position. In *C. alba* and *C. maltha* these ridges project almost straight backward. In *Euxenura* they appear thrust over toward the inner side, and the outer ridge instead of the inner is the more prominent. The whole effect is to make the tarsal head in *Euxenura* seem distorted by a rotation upon the shaft from within outward.

Tibia.—No. 12527. No complete tibia is at hand, but fragments of proximal and distal ends represent this bone. Both specimens of the distal end are of the left limb. They agree most perfectly in both size and characters.

No. 12527 is appreciably smaller than *Euxenura* and is distinctly more like *C. alba*. *Euxenura* appears almost gruine in a superficial way.

Viewed from in front the distal opening of the tendinal tunnel is nearly a perfect circle and the tubercle above it lies just against its outer border. In *C. alba* the tunnel mouth is slightly flattened and in *Euxenura* almost lip-like, while in both the tubercle is removed slightly toward the outer side of the bone. In *C. maltha* a more distinct ridge runs up the shaft from the outer border of the tunnel intake.

C. maltha and *C. alba* are distinguishable from *Euxenura* by the more nearly circular depression into which the intercotylar tuberosity of the tarsus fits.

In the latter, this depression is made gruine in its aspect by being expanded transversely and thus encroaching upon the inner condyle. Seen from the side, the chord of the curved distal profile is more nearly at right angles with the shaft so that the fragment will stand unsupported on its end. In *Euxenura*, a similar fragment falls toward the rear. *C. alba* agrees more nearly with *Euxenura* in this point.

Seen from the rear, the articular surface is not set off from the shaft by a transverse limiting ridge as in *Euxenura* and *Ciconia alba*. Seen from the inner side this latter feature is evidenced by a less abrupt concavity of the posterior profile. The tubercle seen on this side in *Euxenura and C. alba* is much less prominent in *C. maltha*, in fact, the region of ligament attachment is so diffuse as to be scarcely recognizable as a tubercle.

The proximal fragment of the tibia, no. 12529, presents the

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characters of the group, though the edges of the various crests are somewhat fractured or corroded away. No distinctive characters were noticeable in the material at hand.

Beak.—No. 12532. The fragment of the upper mandible preserved is sufficient to show its true stork-like nature and to make it almost certain that there was no recurvature such as appears in *Jabiru*. The most liberal restoration indicates a maximum length of 210 mm. The cross-section in the nareal region

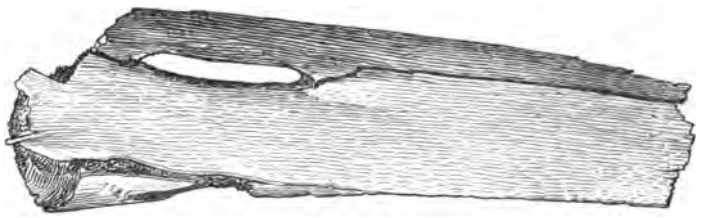

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Fig. 6.—*Ciconia maltha*. Beak fragment from right side. No. 12532, natural size.

Fig. 7.—Cross-section of beak of *Ciconia maltha*, taken at anterior limit of nostrils.

is almost an equilateral triangle. The nostrils are slit-like with edges overhanging above and rounded in below; the proximal and distal extremities are smoothly rounded; there is no internareal septum. The buccal surface of the beak is closed over entirely and marked to a point slightly beyond the nares by a double groove down the median line, and from this point on by a shallow median depression. The fragment corresponds very closely with the same region in *Euxenura*. It is slightly larger, whereas the limb bones appear smaller and less robust. The ridge of the culmen is sharper and the nostrils do not dilate from base toward tip of beak. The profiles are very closely similar.

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Pectoral Arch.—This portion of the skeleton is represented by three coracoids and a fragmentary furcula which includes the symphysis and most of the right clavicle.

Furcula no. 12526 is of the same size as in *Euxenura,* but slightly more slender. The symphyseal region is longer in the sagittal plane, the area of sternal attachment is larger and more oblique with the shafts of the clavicles. The angle included between the clavicles is greater and more distinctly "U" shaped.

The coracoid, no. 12425, is almost identical with that of *Euxenura;* the length is slightly in excess. The shaft is slightly less flattened, and narrows much less abruptly from its extended base toward the head. The facet of the sternal articulation is much more expanded transversely. The head region differs in being longer as measured from the scapular fossa. The dorsal and ventral edges of the head are sharper and more definitely ridged. The concave surface of the head is less richly provided with foramina, and the foramina are smaller, thus suggesting less pneumaticity. The clavicular facet is about equally pronounced. A series of four coracoids from the asphalt beds show these characters to be very constant in the new form.

TABLE OF MEASUREMENTS.

Tibia, distal end, no. 12527.	
Greatest transverse diameter	18.6 mm.
Greatest sagittal diameter of entocondyle	23.3
Greatest sagittal diameter of ectocondyle	22.6
Coracoid, no. 12425.	
Length to inner edge of sternal facet	89.8
Transverse diameter below scapular facet	11.2
Dorsiventral diameter of head	24.1
Least diameter of scapular facet	8.7
Tarso-metatarsus, no. 11202.	
Approximate length along axis	256.0
Least transverse diameter	9.0
Least anteroposterior diameter	5.8
Transverse diameter of proximal end	20.7
Transverse diameter through trochleae	22.9
Beak, no. 12532.	
Depth at anterior end of nostril	23.8
Width at anterior end of nostril	26.5
Length of nostril	23.5
Depth of nostril	3.3

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JABIRU MYCTERIA (Lichtenstein).

MYCTERIA AMERICANA (Auct.)

This splendid stork is represented in the University collection by three tibial fragments and the distal end of a tarsus. Only one specimen, no. 12593, is sufficiently well preserved to show the minute details. For comparison, a specimen of the Recent form was available through the kindness of Mr. F. A. Lucas of the Brooklyn Institute of Arts and Sciences. This specimen shows tarsal measurements of the maximum dimensions as recorded in Coues' Key to North American Birds.[2] The specimens in the University collection are all markedly smaller than the Recent specimen, but there are only minor differences in the structural details.

The fragments show the following dimensions:

Tarso-metatarsus.	
Transverse diameter through trochlea	27.3 mm.
Least transverse diameter of shaft	9.5
Least sagittal diameter of shaft	7.0
Tibio-tarsus, no. 12593. Distal fragment.	
Transverse diameter of condyles	19.1
Sagittal diameter of condyles	23.7

There is in the collection of the Los Angeles City High School a complete tarsus from the asphalt which represents this species. Mr. J. Z. Gilbert of that institution kindly permitted the author to measure the specimen. The length corresponds perfectly with the recorded measurements of the same segment in *Jabiru mycteria* as described in Coues' Key.

GRUIDAE, CRANES.

GRUS MINOR, n. sp.

Type specimen no. 12533. Distal end of left tibio-tarsus. Distinguishable at once from all Recent American species by the diminutive size. The following account is based upon a comparison of the type with a specimen of *G. canadensis* loaned by the United States National Museum.

[2] Coues, E., Key to North Amer. Birds, 5th ed., vol. 2, p. 870.

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Distal trochlear region much less flattened. This character is most clearly shown by a comparison of dimensions given in the table below. The ratio of the greatest transverse diameters in the two species is 100:62, while the ratio of the greatest sagittal diameters is 100:83; or again, the ratio of sagittal to transverse diameters is 100:95 in *G. minor* as against 100:74 in *G. canadensis.*

The entocondyle as seen from the front is proportionately smaller. Its ratio to the ectocondyle is 100:65 in *G. minor,* as against 100:80 in *G. canadensis.*

Other differences not easily measured are noticeable in the intercondylar tubercle, which is less produced and has its summit less knob-shaped. The supratendinal bridge is narrower and is not crossed obliquely from within by a distinct ridge. The region of attachment of the outer end of the tendinous bridge is less flattened.

The generic characters of *Grus* are well displayed in the inequal condyles and the wide intercondylar gorge marked near the middle by a secondary transverse depression; the depressed osseous bridge with its prominent tubercle; the deep extensor groove, rounded where it plunges under the osseous bridge, but flattened to a sharp-lipped slit where it emerges again distally.

In the type specimen the crests and ridges are sharply defined and the texture of the bone is such as to leave no doubt but that it is part of an adult individual.

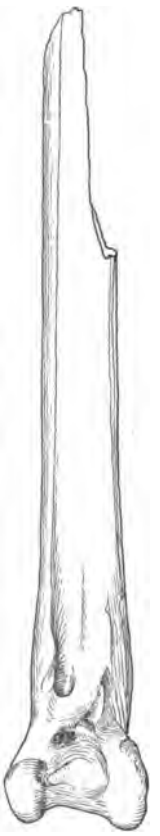

Fig. 8.
Grus minor. Distal end of tibiotarsus from anterior side, natural size.

TABLE OF MEASUREMENTS.

Tibia, no. 12533.

Greatest transverse diameter through condyles	18.8 mm.
Greatest sagittal diameter through condyles	17.9
Depth of anterior aspect of ectocondyle	12.3
Depth of anterior aspect of entocondyle	8.3
Least transverse diameter of shaft	10.2
Least sagittal diameter of shaft	8.3
Width of osseous bridge	5.9

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Grus parvus Marsh, from the post-Pliocene of New Jersey is described as "Somewhat smaller than *Grus canadensis*"[3] and Coues speaks of it as "Nearly as large as the Sandhill Crane."[4] The species is not figured in either paper and no measurements of the tibio-tarsus are recorded. The very small size of the specimen from Rancho La Brea has lead the author to exclude it from Marsh's *Grus proavus.*

GRUS CANADENSIS (Linn.).

This species is represented by a complete tarsus, no. 12590; and the distal end of a tibia, no. 12589. The details correspond quite closely with those exhibited by a Recent specimen from the American Museum of Natural History. The tarsus is of average size. The tibia is appreciably smaller.

In view of the limited amount of the fossil material it would be unwise, perhaps, to do more than call attention to the fact that in the case of four species of waders thus far discussed, the fossil forms are smaller than their nearest relatives at present to be found in the Western Hemisphere.

ARDEIDAE, HERONS.

ARDEA HERODIAS Linn.

The Great Blue Heron is represented in the material thus far examined by the right tarso-metatarsus. This specimen compares quite perfectly with the corresponding bone of *Ardea herodias* at present found in California. A subdivision of the related *Egretta candidissima* has recently been made by Thayer and Bangs[5] by a consideration of the length and robustness of the trsus. The divergence of the Rancho La Brea specimen from the Recent *Ardea herodias,* is, if anything, toward greater robustness. In the absence of a series of skeletons it seems inadvisable to make any distinction in case of the Rancho La Brea form.

[3] Marsh, O. C., Am. Jour. Sci., 3rd ser., vol. 4, p. 261, Oct., 1872.
[4] Coues, E., Key to North Amer. Birds, 5th ed., vol. 2, p. 1090.
[5] Proc. N. Eng. Zool. Club, vol. 4, pp. 39-41, 1909.

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* Univ. Calif. Publ. Bull. Dept. Geol., vol. 5.

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WADING BIRDS
FROM THE
QUATERNARY ASPHALT BEDS
OF
RANCHO LA BREA

BY
LOYE HOLMES MILLER

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